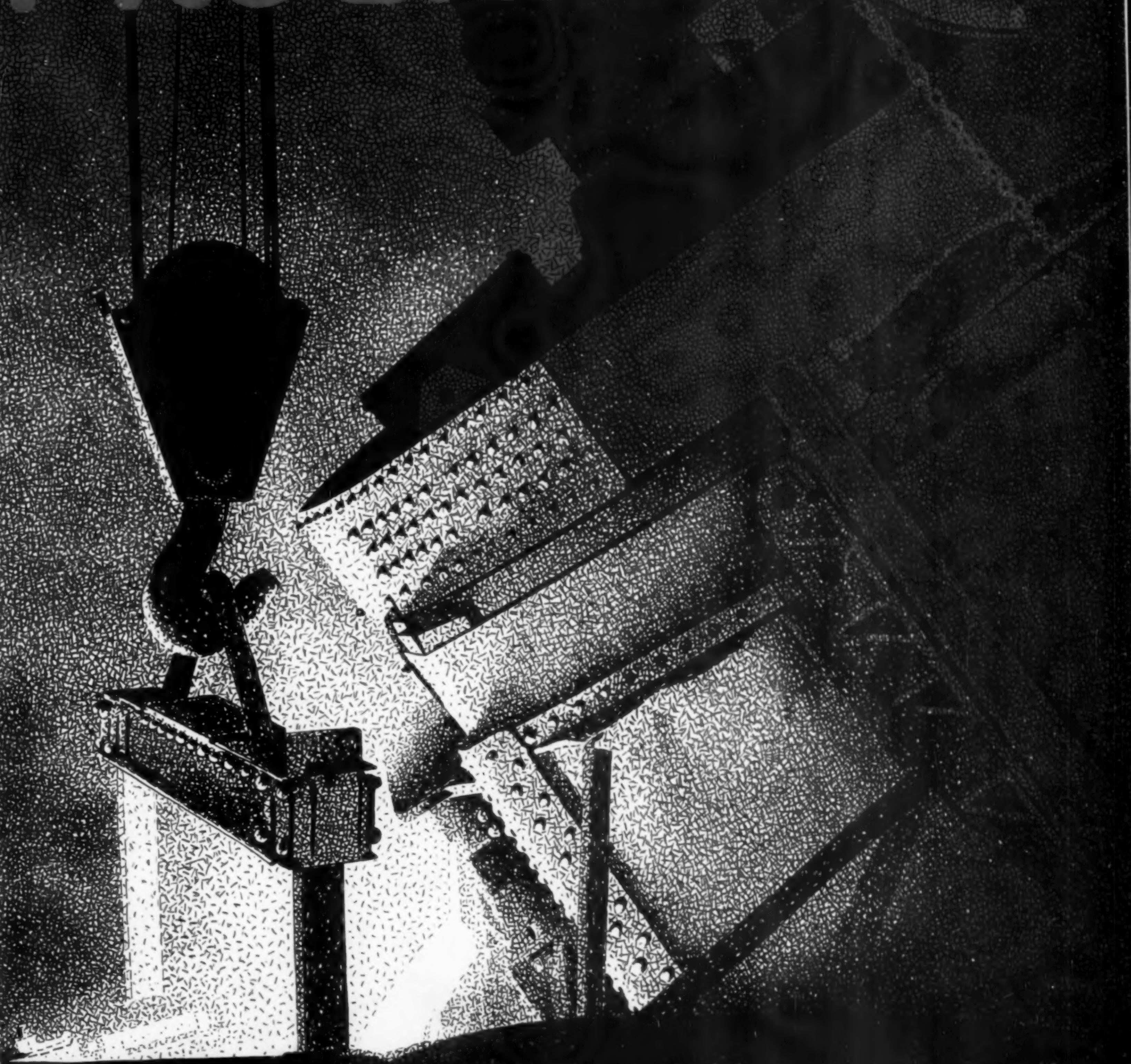
METAL PROGRESS



JANUARY – 1940

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METAL PROGRESS

Vol. 37 *January, 1940* *No. 1*

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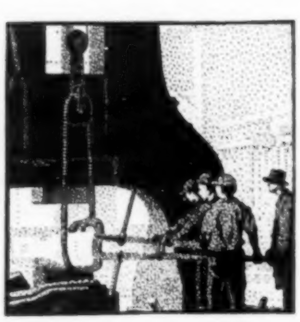
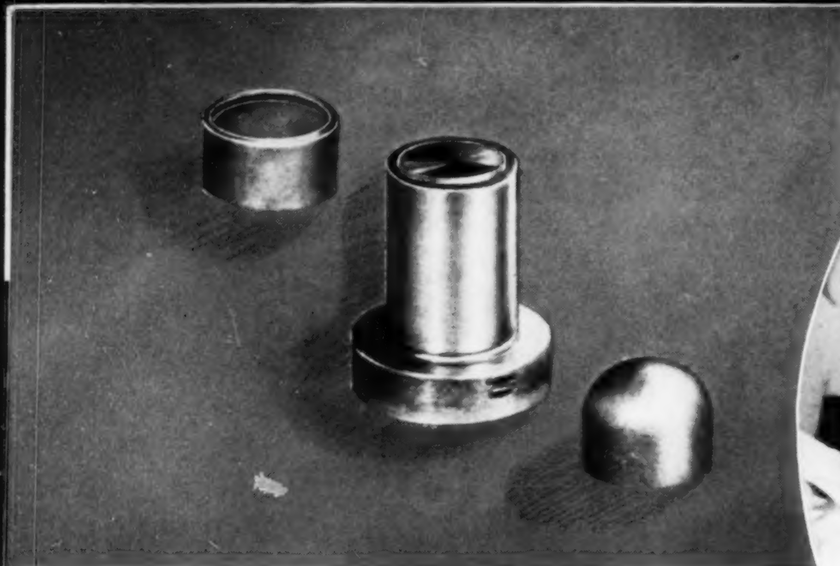
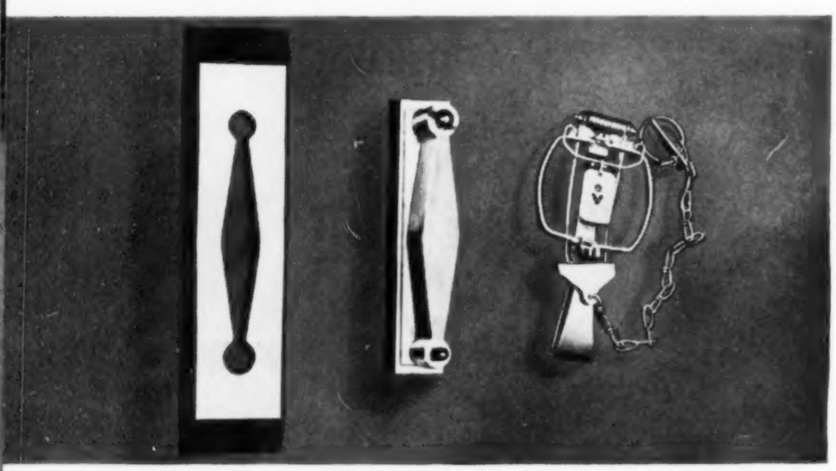
Cover was executed in pen and ink by Carl Sorensen



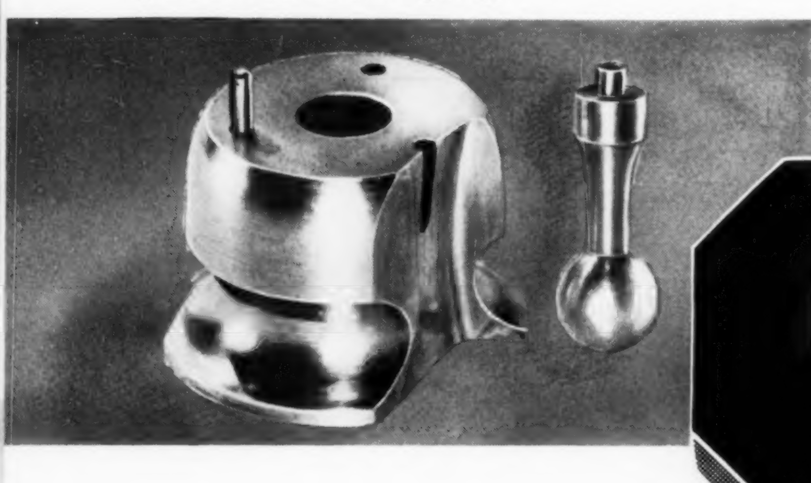


STEPS UP PRODUCTION 25 TIMES—MAKES TOUGH JOB PRACTICAL. Here's a job that's as tough as they come. The bearing race is formed from 1015 steel, 1/8" thick. After the shape at the right is drawn, the round end is flattened and countersunk by impact and compression The best steel previously tried failed at 8,000 pieces—a mere half-day run. Then the tool maker tried the tool steel recommended in Carpenter's Matched Set. Up went punch life to 200,000 pieces. Down went shutdowns to one for every twenty-five formerly necessary. States the shop foreman, "No other tool steel is practical for as tough a job as this."



75% BETTER PRODUCTION—2½ MILLION PIECES—STILL GOING STRONG! The manufacturer of this trap wasn't having tool trouble—all he wanted was extra productive capacity to handle increased business. With Carpenter's Matched Tool Steel Manual, he quickly found the steel he wanted and made the above trap spring die set. Already, this die has cut 2½ million pieces with an average of 150,000 pieces between grinds. With production 75% ahead of the best steel used previously, it's no wonder that he is pleased.

CUSTOMER SAYS, "*IMPROVE THE FINISH*"—SALESMAN ASKS FOR "*MORE SPEED*"—*BOTH NOW HAPPY!* When you are faced with conflicting demands like this, Carpenter's Matched Set Method is an ace-in-the-hole. For instance, in this case, the tool maker was able to put his finger on a tool steel that satisfied both requests immediately. The keen-cutting, tough-edged steel he chose is giving him a production of 300 pieces per hour and 16 hours between grinds—and just look at the finish he is getting.



GET THESE 5 ADVANTAGES AND MANY MORE BESIDES, *with* *Carpenter's* MATCHED TOOL STEELS

1. **Increased Production**
   Because you can put your finger on the best tool steel for each job . . . and give it just the right heat treatment every time.

2. **Lower Tool Steel Inventories**
   Nine tool steels compose the entire Matched Set group. Most shops can handle 90% of their tooling by using only three or four of these steels.

3. **Quick Answers to Questions**
   Complete heat treating data—more than is available for any other tool steels.

4. **Uniform, Sound Steels**
   Carpenter Matched Tool Steels are Acid Disc Inspected, Timbre Tested, and controlled in grain size.

5. **Conveniently Located Warehouses**
   Full stocks located at Carpenter branch warehouses in Chicago, Cleveland, Detroit, Hartford, St. Louis, Indianapolis, and Philadelphia.

The Standard Tool Steels of Industry

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Critical Points

By The Editor

To JONES & LAUGHLIN'S 96-in. continuous sheet mill on the Monongahela River, alongside mid-town Pittsburgh where a strip of land has been won from bluff and river bank. Much has already been printed about these enormous plants, now owned by all the leading steel companies. J. & L. has also published a beautifully illustrated and informative book descriptive of this particular mill, its operation and products, so there is little more to say except words of praise, and comment on the trends of recent practice. JOHN BECK, general metallurgist of the Pittsburgh works, pointed out dozens of stations between slab yard and shipping dock where technical men and recording instruments checked the condition of the metal in process, against the individual schedule written up in advance for each order, large or small. Utmost flexibility of control is necessary to vary these details with promptitude. High pressure water sprays or steam is used at each stand to descale the hot metal effectively; work rolls on the finishing train are frequently replaced and reground; transfer tables, coilers and other handling devices are engineered and maintained so as to avoid scratching. There seemed to be unusual reliance upon tension, cupping and grain size tests, in addition to the ubiquitous micrometer and Rockwell machine. C. L. MCGRANAHAN, superintendent, was especially proud of the increased speed and capacity of the cold rolling mills. Four 54-in. mills, set in tandem, are making a seven-to-one reduction on tinplate strip and delivering at about 2000 ft. per min.; perhaps a minute is lost when a new coil is started. One thing often forgotten by those who wonder where the product of all these mills is going is that a sizable proportion is not rolled to sheet at all, but stops as thin plate or wide skelp. This is one reason why, in contrast to the nearby Irwin plant of Carnegie-Illinois, this J. & L. mill has relatively small departments for making highly finished sheet. This is done at another place.

Sheet Steel at 100 Tons an Hour...

AUDIBLY worrying, within earshot of EDWARD CONDON, about what could be said of importance in a promised lecture on the strength of metal, and he told me how far the mathematical physicist is now able to go in this direction. (He is head of the fundamental research work and associate director of the Westinghouse Research Laboratories in East Pittsburgh.) Roughly translated into engineering parlance, it is something like this: Start with the ideas of quantum dynamics concerning atomic structure. Add to these the simple electrical and magnetic laws which have been used to design generators, motors and transmission lines. Then fix in mind the properties of an electron — its mass and electrical charge — as determined by experiments which are performed on gases and do not appear to have anything to do with metals. Finally, understand the implications of spectroscopic analysis as to the intimate architecture of the atom — nucleus, electron shells, energy quanta. *Then*, all you need is such simple mathematics as vector analysis, calculus and differential equations, and the mathematical physicist can predict the moduli of elasticity, compress-

Calculate a Metal's Properties

ibility, thermal and electrical conductivity, and heat of vaporization of a pure metal. It *has* been done for the alkali metals, and the computed agree with the experimentally derived values within the limits of experimental error. *But*, that still doesn't tell *me* what makes the atoms stick together, even though it tells the mathematical physicist just that!

Talking with Harry Blumberg about the beginnings of the ⊕, and he told me he was the first proofreader on *Transactions* of what was the American Steel Treaters' Society, he being a cub under the late Arthur Henry, metallurgist of the Illinois Tool Works of Chicago, and secretary-treasurer as well as daddy of the infant Society. At that time, he said, there was a campaign for 25,000 members ($5 initiation fee to be waived until membership reached that mark!). Blumberg's present worries, as plant metallurgist for M. W. Kellogg Co. of Jersey City, have to do with big pipe, pressure vessels and heavy plate. "Cold" work and welding on such items should frequently be done at a mild heat, and is so specified, but it is a real shop problem to determine when a pipe-end, for instance, heated by blow torches, is up to or above 300° F., or a heavy plate, warmed in an oven, cools below 400° F. in the straightening press. To take such matters out of the region of spit and guess he has compounded a series of pills, individually colored and with a sharp melting point at 200°, 300° and on by hundreds up to 900° F. (faint visibility). He said he had a lot of fun finding salts or eutectic mixtures that melt within 10° of the required temperature, that would compress or could be bonded simply into a coherent pellet, and that were non-hygroscopic. He calls them "tempills"!

Measuring Black Heat Temperatures

To Latrobe, 50 miles out beyond Pittsburgh in the sunny Pennsylvania hills, to visit friends at Vanadium-Alloys Steel Co. Inspecting the plants with Burns George, metallurgical engineer, was impressed with the care taken to avoid surface changes in high speed steel bars — the principal product. Ingots are heated in coal-fired furnaces, with smoky flame, but scaled generously so the cogging hammers break away to clean metal; seemingly the iron burns more rapidly than the carbon does. Forged billets are heated in new gas-fired furnaces, under metallurgical control, where flame conditions are maintained to prevent decarburization. These furnaces are overfired; they vent at the opposite side, behind curtain walls, into roof openings at the skewbacks. Natural gas passes through a needle valve to a venturi surrounded by low pressure air, and the resulting flame is of the luminous combustion type. Adjustments are now made by hand; temperature control is by a valve in the gas line, and atmosphere control is by lever which simultaneously moves a gate in the air main and dampers at all vents. (Adam Steever at Columbia Tool Steel Co. in Chicago Heights and Bob Schlumpf at Hughes Tool Co. in Houston are also staunch believers — and practitioners — in flame control on forging furnaces.) Annealing of toolsteel is done in tightly sealed containers — rods in pipes, and coils in doughnut-shaped boxes — packed in mixtures that vary with the steel. Heating to 1600° F. for 8 to 10 hr. and pot cooling will soften best for cold drawing operations. Harry Good, superintendent of the subsidiary Anchor Drawn Steel Co., said that comparatively small drafts were the most that high speed can stand before a process anneal at about 1400° F. is necessary.

High Speed Steel to the Very Surface

To New Kensington, and was disappointed to find that the beautiful white metal so lavishly used on the exterior of Aluminum Research Laboratories had acquired a rough covering of black soot. Charles Magill, who promotes the architectural uses of aluminum, showed me how bare metal, as erected ten years or more ago, would slowly acquire a thin layer of white oxide, rather loose in texture and seemingly having an affinity for the sooty fog of industrial atmospheres. Scrub off this coating and the bright aluminum is underneath, but even so the wide use of aluminum for exterior decoration (now absorbing several million pounds of metal each year) awaited the so-called alumilite process. In this, a dense, almost transparent coating of aluminum oxide is artificially formed on the shapes and castings to be exposed to the weather. While dirt and soot will settle on this surface, as it will on anything exposed, even plate glass, it does not mix with the permanently adherent oxide, and so is washed off ever so much more

Extrusions for Architectural Trim and for Aircraft Ribs

easily — sometimes even by rain water. MAGILL is also in charge of extrusion sales for the Aluminum Co., for the very good reason that the numerous shapes used for muntins, sash, frames and casings are extruded products. Many of these are hollow, and the problem of making such a hollow shape with correct wall thickness is a difficult one. It has been ingeniously solved in the largest shapes by controlling the flow of the metal through specially constructed dies, so that more than one shape passes over a mandrel into the final form under such pressure and temperature that abutting edges are perfectly welded. Long, narrow extruded shapes, even of magnesium alloys for aircraft members up to 24 in. wide, are made as curved extrusions which are then flattened to final shape.

SPENT the all-too-short afternoon hours with RICHARD TEMPLIN. (Everybody knows DICK is Chief Engineer of Tests at the Aluminum Research Laboratories.) He is now installing the world's most powerful testing machine by Emery-Southwark to supplement about as complete a group of equipment as can be seen anywhere. This monster occupies a three-story annex; its hydraulic pumps and auxiliaries in the cellar alone are worthy of the engine room on a small tanker. TEMPLIN's eyes really gleam, though, when he talks about the accuracy of his tests. Precision, precision, precision — this passion extends far beyond the confines of New Kensington, for twice a year one of his assistants carries proving rings and calibrating boxes to all the plants and laboratories, and if any testing machine is more than 1% in error at any part of its working range, it is decommissioned until repaired. Aside from a staggering amount of fatigue testing, two things stick in memory as unique: First is a photometer, made by Leeds and Northrup on principles developed by Alcoa scientists, which rapidly and automatically charts the density of spectral lines — a boon to quantitative spectrographic analysis. The other is the testing of sheet metal in *compression;* a pack of sheets is milled into a precise prism and firmly, but not too firmly, held in a fixture and placed between accurately parallel heads in a hydraulic testing machine. (Note again the words "precise" and "accurate".) A stress-strain curve will then give the modulus and the true yield point in compression, reproducible figures that are very important — even if all too frequently ignored — in beam, bulkhead, stiffener and column design.

Precision, Accuracy, Precision!

LITERARY NOTE: Aluminum Research Laboratories are now publishing occasional monographs containing their major studies on structural design. What with the desire of learned and engineering societies to keep down the mounting publication expense, and the avoidance of theory by engineering and technical magazines, there seemed to be no other outlet for this great body of information.

WITH FREDERICK MCINTOSH, director of metallurgy of Crucible Steel Co. of America, to the LaBelle Works in Allegheny City where crucible melting still survives in the one plant of the nine which made crucible steel at the time of their merger in 1900. Huntsman's process, invented just two centuries ago and unrivaled for toolsteels for at least 150 years, is all but extinct in America, there being only one 30-pot gas-fired furnace now operating, on exacting specialties like carbon steels for cold header dies. VAN FISHER has photographed the men and the methods at LaBelle, and METAL PROGRESS will present this pictorial story in a nearby issue. In company with Manager CLARENCE WISE and Metallurgist KENNETH METCALFE, enjoyed hugely a visit to this long established, bustling plant where steel melting by traditional methods elbows such modern equipment as Gogan quenching presses for hardening agricultural disks. (It appears that plowshare steel must be scour resistant, tough, hard, and slippery to sticky earth. Seemingly one that rusts easily without pitting, yet sheds its rust and polishes itself in the first few feet of furrow, is the most satisfactory.)

LaBelle plant — an old-time toolsteel mill

Another manufacturing anachronism — although a piece of admirable craftsmanship — is the forging of toolsteel rounds and hexes so accurately to shape that some customers believe they are rolled unless they are later marred with hammer-marks! One of the small merchant mills (cross-country type) makes shear and knife bevels, and so many miles of blades for lawn mowers that it might be called "the lawn mower mill". A small plate mill was rolling 12% manganese steel — an analysis similar to Hadfield's cast manganese steel for batter and wear resistance — with no more effort, as they handle it, than though it were plain carbon steel.

Last February Mr. Tranter spoke on "Development of the Basic Openhearth Process" to the Notre Dame Chapter ⊕, and it was such an excellent summary of the mechanical improvements in steel making that it should be available to a far wider audience

The Openhearth Furnace and its Auxiliaries

By G. D. Tranter
General Supt., Middletown (Ohio) Division
The American Rolling Mill Co.

Basic openhearth steel making is now highly developed in all respects, not only as to furnace itself but also as to its auxiliaries and metallurgical operation. The broad outlines of these matters are well enough known to ASMembers so that an elementary account can be dispensed with. However it is very interesting to go back into the early history and see the tremendous progress that has been made in furnace design and auxiliary equipment.

One of the early ideas was to place the checker chambers (regenerators) beneath the hearth. This design presented a serious problem when a breakout occurred through the bottom — as it all too frequently did — allowing the steel to run down into the chambers beneath. The circular type of furnace was next tried in an endeavor to utilize the fuel and to distribute the heat over the surface of the charge more effectively, but it was abandoned due to high maintenance cost.

Auxiliary equipment was a limiting factor during the early days. Electric cranes were unheard of and various types of lifting devices and derricks were used to handle the ladle on the pit side. The openhearth pit was a very congested spot and the equipment was rather crude. As late as the year 1905 chains were often used instead of wire rope cables on the ladle crane.

On account of the limited size of blooming mills, ingots were rather small and usually filled by the bottom pour method. With the already small working space, the additional feature of bottom pouring further congested the pit, which not only caused delays but also presented a serious safety hazard.

The charging side of the furnace was as antiquated as the pit. Scrap, pig iron and limestone were hauled to the furnace by mules where the material was placed on a peel and pushed into the furnace by muscle. The electric charging machine now permits rapid charging of large tonnages — in fact, the charging machine has probably been the largest single factor in the increased capacity of the modern furnace.

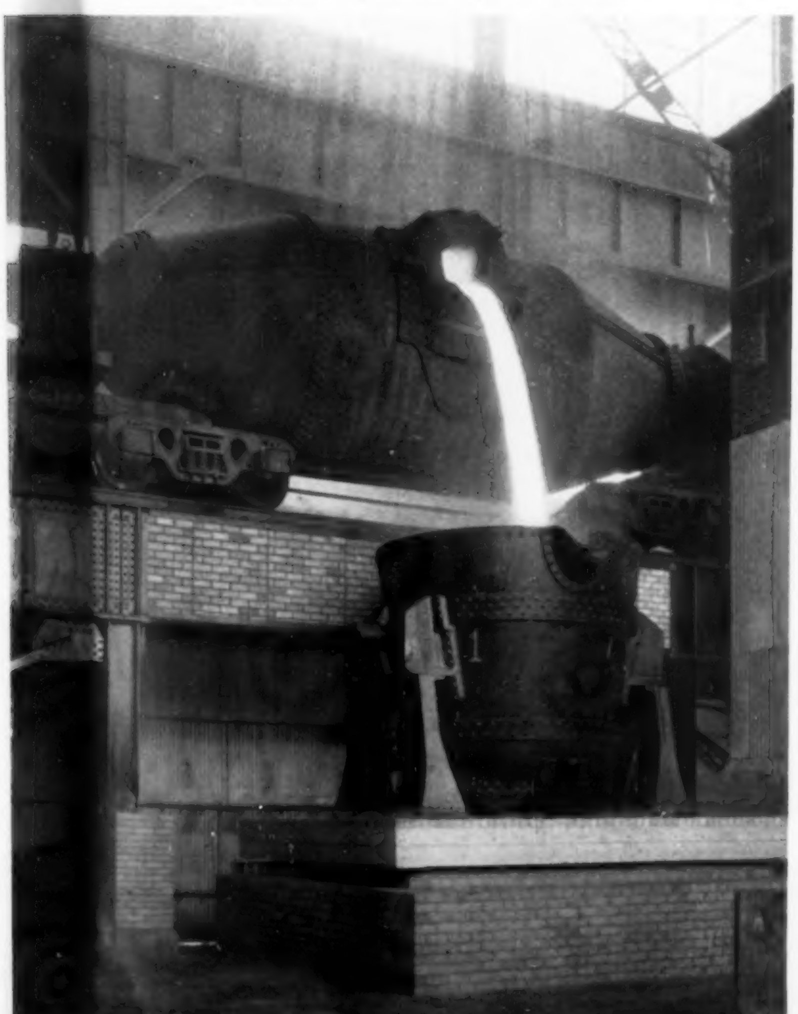
Hot metal has greatly speeded up production. By means of large stationary mixers and Pugh hot metal cars (barrel shaped), molten pig iron can be stored until required by the steel maker. Molten pig iron is being transported as far as 11 miles requiring about 30 min. for the trip. By means of refractory insulation it is possible to hold the molten metal in the mixer car from 12 to 18 hr. without serious difficulty. Hot metal after being poured from the mixer into the transfer ladle is

weighed, carried to the furnace and poured into the hearth by means of a spout or runner placed through a door. The use of hot metal conserves heat and hastens the reactions in the charge, the total saving in time amounting to about 15%.

The hearth into which the raw materials are charged and which must withstand the erosion of the slag and metal is a rectangular brick structure, lined with magnesite which has been subsequently "fused in". Success in steel making depends on the quality of the refractories and the skill and technique of "fusing in" the bottom. If proper materials and workmanship are used, the bottom will last from 10 to 15 years with only the regular patching between heats and possibly an occasional "washing out" and rebuilding of a portion of the flat section.

The early furnaces were built with solid bottoms. Refractories then available could not withstand the high temperatures, with the result that large puddles or holes in the bottom could not be rabbled or cleaned out properly. Often the steel soaked down into the solid hearth as much as eight feet. Improvement in refractories has greatly assisted the operator in keeping the furnace lining in good condition, a fundamental requirement for making high quality steels.

Pouring Pig Iron From Hot Metal Car (Pugh Design) Into Transfer Ladle for Openhearth Furnace. The clean, slicked-up appearance is not re-touching; just the very first operation of a brand-new installation



Early openhearth operators had to be satisfied with what refractories they found at hand. They were of mediocre quality and the life of the furnace was very short, maintenance costs were high, and the efficiency of the furnace dropped rapidly due to premature burning away of the port lines. Formerly a 40-ton furnace made about 100 heats during the campaign, which is quite in contrast to the 350 to 500 heats expected today. However, with highly developed refractories for almost every purpose, the problem of getting 300 to 400 heats today is considerably less than obtaining 100 heats on the earlier furnaces.

During the first four decades of openhearth development, prior to the turn of the century, work in the steel making departments was of the extremely hard physical type. Improvement in working conditions, particularly since the establishment of the 8-hr. day some 20 years ago, the introduction of labor saving devices, greater attention to factors affecting the comfort and safety of the worker, and improvement in the equipment, have all resulted in attracting a higher type of personnel into the openhearth shop.

The dolomite machine has eliminated much of the hard work required to keep the bottom and banks in condition. It is a portable hopper, with a short section of rapidly moving belt conveyor just under the gate which can throw a steady stream of granular material clear across a large furnace. Its cost is more than saved by the time saved in repairs at the slag line after each heat. Grab buckets are used in the pit to load up slag and debris promptly, thus providing better working conditions as to space and temperature.

Tracks for operating standard railroad cars in the pit have done much to reduce delays to the furnace because of delayed pit work. The use of a magnet on the floor crane has also facilitated the work on the charging floor and makes it possible to maintain clean and orderly working conditions.

Openhearth Layout

The layout of the main building consists in placing the furnaces end to end adjacent to each other. The number is usually limited to 12 to 16; where too many furnaces are in a single line, charging delays occur and crane

Interior of Furnace, Rebuilt Above Slag Line. Note inclined backwall at right, extra long arch brick above and water-cooled block over port at far end

service for handling the ladles is inadequate, especially when several furnaces are ready to tap at the same time.

The openhearth plant should also provide for a well laid-out stock yard with a covered crane runway, including fast cranes, a straight line track layout system and ample locomotive facilities. In addition to this equipment, storage bins and buildings must be provided for large stocks of materials such as brick, magnesite, chrome ore and burned dolomite.

Ample platform space is also necessary in the rear of the furnace to facilitate tapping, and to cope with emergencies. The back standing supporting the furnace runners should be easily accessible for the safety of men tapping the heat.

It goes without saying that furnace design is very important. A poorly designed furnace is frequently shut down, and even minor repairs to a good furnace not only affect output but have a decidedly detrimental effect on quality. It is necessary to shut off the fuel during most repairs which delays the heat and interrupts the normal reactions during melting or refining periods. Such heats are termed "soaker" heats and are usually de-graded to orders where quality requirements are very mediocre. The frequency of repairs also depends on the operating technique and fuel application.

In the design of an openhearth furnace rigid mathematical formulas must be supplemented by practical experience. The gradual evolution of the furnace has been accomplished through years of discarding the impractical and incorporating the successful. That does not mean that the various features or sections of the furnace do not bear a definite relationship to each other in size and location. These dimensions are largely governed by the capacity or amount of steel to be made in each heat and the type of fuel to be used. Various flue sections are proportioned to admit the necessary quantity of air to burn the fuel and to discharge the products of combustion rapidly.

In a well-designed or balanced furnace, the effective draft of the stack extends to the center of the hearth; the "stack effect" of the regenerators and uptakes is thus sufficient to carry the incoming air to the point of combustion. The pressure in the hearth should be almost in equilibrium with the atmosphere with a slight tendency toward the positive side.

The steel binding, forming the framework of the furnace proper, consists of vertical uprights or buckstays to which are secured the

cross rods and longitudinal members. Structural steel and cast buckstays, once popular, have been discarded in favor of heavy rolled sections, each buckstay in a large furnace now requiring the entire product of an 18x20 ingot. Rigid bindings instead of adjustable tie rods across the main roof span have become general. Many operators have found that rigid binding (where no adjustment is made upon heating or cooling) holds the contour of the roof more normal. Welding of hearth plates, beams, chill boxes and other members has been general.

The backwall of the furnace has undergone considerable development during the past 10 years. Backwalls were formerly constructed of silica brick, but the tendency of the flame to sweep along the rear of the furnace (due possibly to air currents from doors on the front side) caused this portion to burn out rapidly.

Experiments were next made using chrome ore in large pieces reinforced with tie bars. While this was an improvement over the silica brick, it was very costly and the duration did not justify the expense. "Metal-kase" brick was also tried but also proved rather expensive.

The most efficient type of backwall is known as the sloping or Naismith backwall. To build it the rear buckstays must be bent so that the upper section of the backwall, above the slag line, inclines outward. The angle is flatter than the angle of repose of crushed dolomite, so the "slag line" can be built clear up to the skew back of the roof. Repairs by replacement, using a dolomite machine, are then made after each heat thus protecting the brickwork, which now lasts for several years. A further improvement of the sloping backwall consists in the use of clips or braces to reinforce the steel plates between buckstays.

Regenerative Control

A regenerative or reversing type of furnace requires a mechanism between the hearth and the stack to alternate the direction of draft through the system.

Various types of reversing valves have been developed, some of which are remarkably well designed for maximum efficiency together with easy installation and operation. Reversing the direction of gas flow may also be accomplished by using the Isley Venturi stack principle, which eliminates reversing valves in the main flues.

This consists of two separate Venturi-type ejector tubes connected with the flues on either end of the furnace. Each tube contains a blast pipe of the proper shape and size served by a low pressure fan. The throat of the tube contains a butterfly damper and the tube is brick lined and insulated up to the throat. Both fans operate simultaneously; the one connected with the outgoing side delivers air at a rate sufficient to lift the flue gas out of the system and into the atmosphere through the open throat of the tube. The fan which is connected with the ingoing side is adjusted to deliver just enough air for combustion, the damper in the throat of this tube being closed. When the temperature exchange in the regenerators has reached the proper point, as indicated by a recording pyrometer, fans are reversed in function by simple remote controls operated by the furnace men or directly connected to a relay on the pyrometer.

This system of mechanical draft is capable of any desired performance with constant uniformity. In order to increase or decrease the general rate of flue gas discharge, it is only necessary to adjust the air per minute output of the ejector fan. Likewise the ingoing air is similarly regulated to suit the desired rate of combustion and furnace atmosphere. Since the entry of the combustion air is almost the same point at which the waste gases are being released to the atmosphere, not only the regenerator chambers, but also the flues and the tubes themselves, become regenerative so that the final waste gas temperatures may be as low as 800° F. and even lower.

Other forms of forced draft have proven

Air Leaks Into Regenerators Have Been Prevented by Steel Casings, and Radiation Saved by Adequate Insulation

very satisfactory among which is the Pratt-Daniel ejector with a Venturi placed near the top of the conventional stack, and forced air supplied through an outside tube from a motor-driven fan at the base. Natural draft furnaces have been greatly improved and the more modern installations have provided for a stack of ample size, equipped with a motor-operated stack damper for rapid adjustment, together with a blast fan for supplying and controlling the necessary quantity of combustion air.

Waste heat boilers are also used in some plants. A portion of the waste gases is by-passed through the boiler by means of a fan system. Certain economies are derived, especially where used to generate processing steam.

Checker design and construction have also undergone considerable changes. Special shapes and methods for laying up the brickwork are sometimes used to conserve heat more effectively. Features under study are: Maximum brick surface exposed, passageways for the free flow of gases, thin sections effective throughout the brick for rapid heat absorption and release, together with reasonable maintenance costs. Flat suspended roofs over the regenerator chambers distribute the waste gases more evenly through the checker work. It is desirable to build the regenerators as large as possible (within certain limits, of course, depending upon the size of the furnace). Capacity should be gained by increased depth rather than width, as the wide chamber does not distribute the gases uniformly. The depth is usually limited by the danger of ground water or flood, and the height by the charging floor.

Insulation and Combustion Control

Experimental results with insulation have encouraged its use in practically every section of the furnace. Insulated slag pockets, checker chambers and flues have been more or less standard practice for a number of years. More recently roofs, furnace hearths and end-wall bulkheads have been insulated. Very satisfactory performance with both fuel savings and increased roof life have been reported from plants using insulated roofs. Insulation of the furnace hearths has reduced radiation through the pan, and decreased the thickness of the brick lining, thus allowing more space for larger furnace charges.

Improvement in combustion has been given much deserved attention. More efficient methods of introducing fuel into the furnace through improved burner design, better regulation of air and fuel input, together with various types of automatic and manually operated controls, have saved much fuel with a consequent improvement in the life of the furnace. Many shops today are producing with a fuel consumption of $3\frac{1}{2}$ to 4 million B.t.u. per ton of steel. Combinations of two fuels are frequently used with better results and lower total fuel cost than heretofore obtainable with either fuel alone.

Temperature control in various sections of the furnace has been adopted rather universally. Furnace reversals are made in accordance with certain predetermined temperature variations and the reversing mechanism is operated automatically or manually on automatic signal by the furnace helper. Automatic reversal, of course, eliminates the human element and has the advantage of more regular reversals, permits the helper to assist on adjacent furnaces in emergencies and provides better balanced thermal condition in the regenerative system. Roof temperature controls are now available which reduce or shut off the fuel if the roof temperature becomes excessive.

Use of motor-operated fans to supply pressure air for combustion purposes, with the fan speed calibrated into cubic feet of air delivered, has been a step forward in eliminating one variable when merely an open or dampered air inlet was relied upon. Air flow meters also give a direct measurement of the air supplied. Furnace draft is easily regulated with variable speed motors and forced draft, or by the use of motor-operated stack dampers when natural draft is used. The rate of fuel input is comparatively easy to adjust, but changes in draft and air are not always made accordingly, and the automatic feature of certain combustion control systems lends itself very effectively to a better balance of these factors.

Considering the mechanical and instrumental aids the steel melters now possess and comparing them with the handicaps faced and successfully overcome by their predecessors, one cannot but admire the strength and skill of those men who introduced the steel age of our industrial civilization.

Comparable to the above mentioned improvement in furnace and its accessories have come equally important changes in pit practice and general metallurgical control — but that is the subject of a subsequent article.

Standardized life tests for electrical resistors have been accepted by the industry, but since these are made at such a high temperature that life is unduly short, the problem now solved by Mr. Bash concerns the expected life during normal operation

Life Expectancy of Electrical Heating Elements

IN AN ARTICLE entitled "Estimating Life of Electrical Heating Elements" in METAL PROGRESS for February 1938, the author outlined the steps leading up to the writing of specification B 76-36 of the American Society for Testing Materials covering an accelerated life test for electrical heating materials. (This is in reality a standardized method of test to determine resistance to oxidation at high temperatures of metallic resistors.) He also showed how it was possible to foretell, within reasonable limits, the life expectancy of a wire at any temperature, when the standard test data are known, on the assumption that conditions of oxidation would be similar and that no other types of corrosion were present. It was also expected that it would be possible to estimate the life of a heating element in an appliance or furnace under new conditions of temperature, providing the life was known for existing conditions of temperature.

This information was given for our alloy known as Nichrome V (nominally 80% nickel, 20% chromium) and curves were plotted showing the relation between life at various temperatures and life as determined at the standard test temperature.

Another of our alloys, called Nichrome I and nominally 60% nickel, 16% chromium and 24% iron, is much used for lower operating temperatures (up to 1700° F.). It also has a constant life-temperature relation. The constants have been calculated and are now to be presented. Life test data have been taken by the same method as previously reported, and it is found similarly that the alloy as recently improved metallurgically has an entirely different slope and constant from that previously made to the same nominal composition.

The equation giving the relation between the variables involved for nickel-chromium and nickel-chromium-iron heating elements is stated in its simplest form as follows:

$$\log L = ST + K$$

in which L = hours of test life, S = slope of the curve, T = temperature and K = a constant. In this equation, the figure for total hours of life is used, although it would apply equally well to a figure for "useful life". This will be applicable for temperature ranges where the ratio between "useful life" (test time required to increase 10% in resistance) and "total life" is constant. In the case of other alloys, where the ratio of useful to total life is erratic and where the useful life is short in comparison, it is preferable to use the hours of useful life in the above equation.

In order to show why it is not possible to

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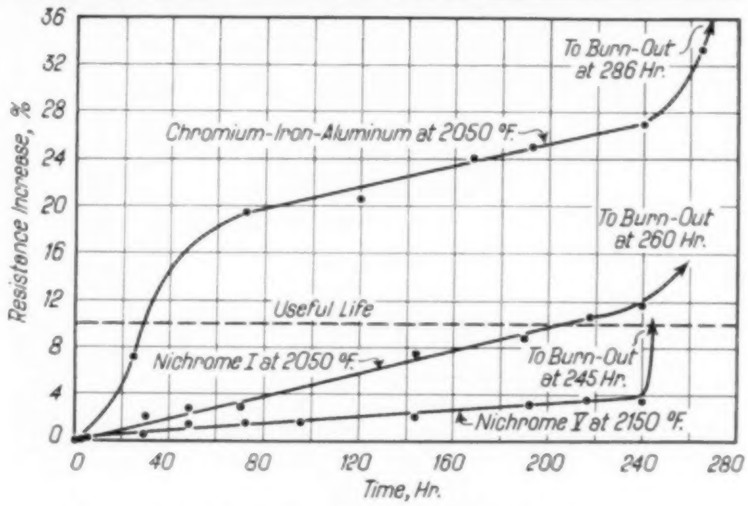
apply the formula given above to all heating materials, or to the same class of alloy made by different practices, there is plotted in the figure at right the time-resistance curves for Nichrome V, Nichrome I and a chromium-iron-aluminum alloy sold for similar applications. These were taken from standard life tests. It is apparent that if calculations for all three of these alloys were based on their total life, it would be difficult and misleading to apply it to the sinuous curve for chromium-iron-aluminum. If calculations of life are based on useful life the slope S and constant K could be calculated using the formula and methods outlined above.



Typical Life Test Curves for 0.025-In. Wire
(Acknowledgments to J. M. Lohr)

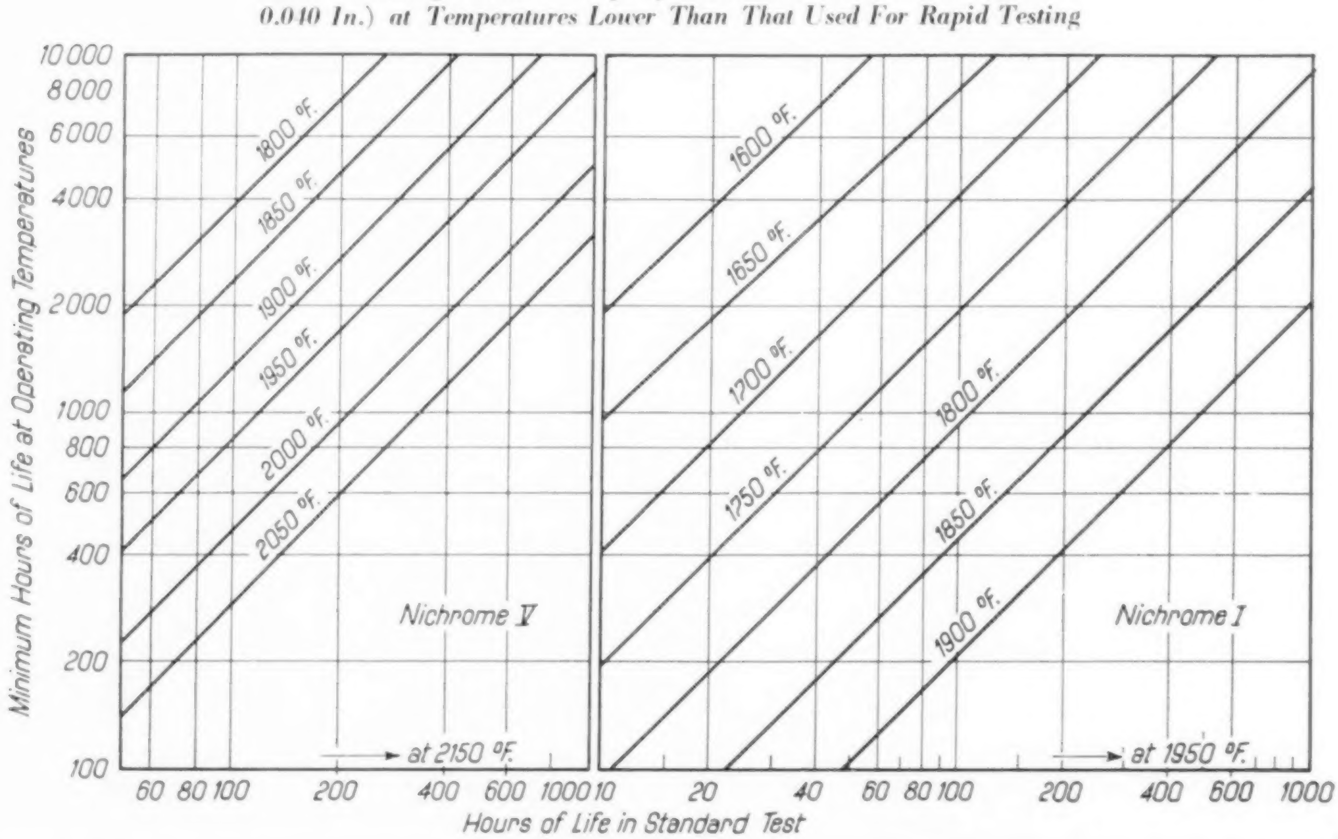
The constants for Nichrome V and Nichrome I in the life-temperature equation, figured from data taken from hundreds of life tests at various temperatures are:

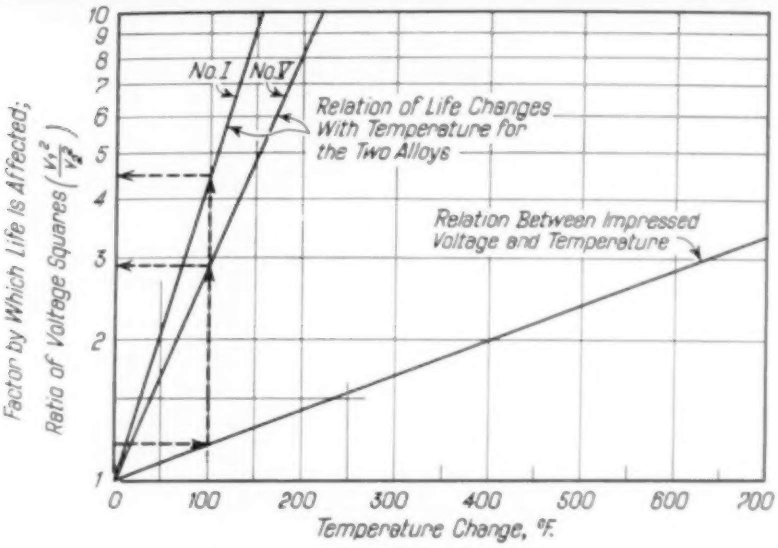
	Nichrome V	Nichrome I
Slope S	-0.00459	-0.00649
Constant K	11.760	14.846

These figures are for the standards of comparison used in making life tests, but the same constants can be determined for any particular heat by using the standard life test data and the above equation.

The above values are applicable only to the alloys as noted, made by improved metallurgical and mechanical technique, and not to other

Curves Showing Minimum Life of Modern Resistance Wire (0.020 to 0.040 In.) at Temperatures Lower Than That Used For Rapid Testing





Curves Calculated by G. C. Stauffer Showing Changes in Temperature and Life of Heating Elements as the Impressed Voltage Changes. See text for solution of problem indicated by dotted lines

alloys made by different processes or by other manufacturers. They are valid only to sizes of wire elements between 0.020 and 0.040 in. (No. 24 to No. 18 American wire gage). They will also apply only under oxidizing conditions as met in the standard A.S.T.M. test method where other types of corrosion are not present.

Knowing the life of the wire for any temperature, the value of K for a particular lot can be determined by using the slope values and substituting in the equation. The life can then be calculated at any other temperature within a reasonable range. This has been done and lines are plotted on double logarithmic coordinates in the diagrams at the bottom of the page at left, both for Nichrome V on the basis of life at 2150° F. and for Nichrome I wire in which life is given for various temperatures when the standard life test at 1950° F. is known.

At the present time, the standard A.S.T.M. life test on Nichrome I type alloys calls for a starting temperature of 2050° F. This temperature of test was established because it was necessary to reach burnout in a time between 100 and 300 hr. A careful study of the life-temperature relation of Nichrome I has shown that the curve is only a straight line up to 1950° F. It is therefore desirable to calculate the life on tests made at temperatures no higher than 1950° F., and this has been done for the second figure.

For applications where material is to be used for heating elements in electrical furnaces to be operated at a constant temperature, a constant temperature test similar to that described by Hoyt and Scheil in Ⓜ *Transactions* for December 1935, or a test on the order of the standard A.S.T.M. life test, in which the temperature is readjusted to a particular value at intervals, is recommended.

A practical application of this information would be for a manufacturer who wishes to know what effect varying voltage will have upon the life of the element in a household appliance. The temperature attained by the heating element depends upon the input of electrical energy in watts per square inch of element surface and the rate of heat loss from the surface by radiation, convection and conduction. Its life will depend upon the temperature at which it operates, providing there is no corrosion present. It is assumed that the life is satisfactory at the normal operating voltage. In cases where the voltage varies, it is possible to predict the change in the life with increasing or decreasing potential. The temperature of the surface of the element is a function of the watts per square inch of the element surface. For an element of a given size and length, the temperature will vary with the watts input, since the surface area remains the same. Since the life of the element is proportional to the log of the temperature, it is possible to plot observed changes in temperature against variations in wattage input and in life.

In the third figure, calculated by G. C. Stauffer, the wattage change is expressed as the ratio of the square of the impressed voltages to which it is proportional, and is plotted against temperature change. It is assumed that the element resistance does not change with temperature (an assumption sufficiently accurate for practical purposes).

At the top of the figure are plotted curves for Nichrome I and Nichrome V giving the relation between temperature change of an element and the factor by which the life may be multiplied or divided, depending upon whether the voltage increases or decreases with resultant increase or decrease of temperature.

A concrete example of the effect of a voltage change upon the life of an element is as follows: Consider that the present voltage is 115 and the contemplated voltage is 126. Dividing the square of 126 by the square of 115 the change is 1.2.

The intercept on the temperature change curve shows 100° F. *increase* in temperature. If we now refer to the curves at the top of the diagram, going up the 100° line, we find that if Nichrome V is used, the life of the element at 126 volts will be 1/2.9 or 0.345 of the life of the heating element at 115 volts. In the case of Nichrome I, the life will be 1/4.5 or 0.222 of its life at 115 volts. Similarly, if the temperature were dropped 100° F. the life would be increased 2.9 times and 4.5 times, respectively.

(It must be understood that these figures will only apply within the limitations of maximum operating temperatures of the two alloys.)

The temperature of a heating element at any specified impressed voltage can be readily determined with the use of an optical pyrometer. The change in temperature with the change in voltage can then be estimated from the lower line in the last diagram.

Likewise, the life of an appliance using a wire element in the size range of 0.020 to 0.040 in. can be estimated where no corrosion conditions are encountered, by assuming a minimum life expectancy. This is the life that would be obtained under standard life test conditions at the temperature of operation, and the time can be calculated from the formula given above.

In the case of electric furnace elements, subject to oxidation only, life can also be calculated from known data. Knowing the temperature of operation of the elements and the life that has been obtained in a particular instance, the life at any other temperature can be determined by reference to the second pair of curves or the formula.

Another case where life data are of direct interest is in using fine ribbons rolled from round wire. These are of the order of 0.032 to 0.125 in. wide by 0.0035 to 0.008 in. thick and are used widely in the manufacture of toasters and other appliances. Life tests were made on three thicknesses rolled from the same piece of round wire and it was found that the life at the same temperature was, as might be expected, directly proportional to the thickness. With this information and knowing the temperature obtained under a particular set of conditions for a certain size of ribbon, an estimate may be made of the temperature and resulting life, using another size of ribbon. The temperature of the ribbon in two appliances under similar conditions is proportional to the watts per square inch dissipation.

High Speed Light Weight Trains

By Charles T. Ripley
Chairman, A.S.M.E. Railroad Division
(Formerly Chief Mechanical Engineer, Santa Fe Railroad)

Extracts from address before American Society of Mechanical Engineers, September, 1939

ADVENT of the high speed, light weight train awaited several preliminary developments. One was the demonstration of reliability of two-cycle diesel engines on branch lines. Another was the discovery that lost passengers could be regained by such improvements as air conditioning. The third was the production of new alloys and their fabrication by welding.

The first of these trains consisted of three or four cars with 600-h.p. diesel engines in the head car. They were made as small and light as possible in order to hold down the power requirements and to enable them to compete with buses and private automobiles by giving cheap transportation. They were streamlined to reduce power requirements and for public appeal. The reaction of the traveling public was so favorable that there was an immediate demand for more elaborate trains for longer runs. Low first cost was soon lost sight of in this development.

Most of the early trains had articulated cars because it was thought that this design reduced weight and gave better riding conditions. It developed, however, that neither of these factors proved to be important. In the last few years practically all the light weight cars have been built as individual units with standard floor and coupler heights and standard outside dimensions, so that they can be associated with any standard car. The weights of these cars were reduced about 40% from those of the conventional structural steel cars, and thus four-wheel trucks could be used.

As shown in ALBERT E. STUEBING's article in METAL PROGRESS for July 1938, the new light weight cars are being designed and built just as strong and safe as the older heavy types, by better engineering, stronger materials, and improved methods of fabrication. New welding technique largely eliminates the human element and should be preferable to the old riveting practice.

Several of the early trains were built of aluminum alloys but in recent years the majority of them have been built of stainless steel or low alloy, high tensile steel. *(Continued on page 74)*

American Society of Mechanical Engineers hear about the latest attempts to roll continuous strip direct from molten metal—also more ordinary metallurgical problems, such as correct design for long life of forged rolls, and the influence of grain size on the wear of bearings

Rolling of Sheet Metal, Direct From Liquid

During the 60th annual meeting held in Philadelphia in December, the American Society of Mechanical Engineers was given a glimpse into the future through an illustrated talk by C. W. Hazlett on "The Production of Strip Metal of High Melting Points Directly from Molten Metal". A couple of years ago Mr. Hazlett used motion pictures in describing the direct rolling of non-ferrous metals to the New York Chapter of the . He used the same medium in showing more recent progress which appears to have brought the process to the threshold of practical rolling of steel strip and tinplate, an application which he expects to see realized in the course of the next two or three years in the commercial production of steel strip of 0.015 to 0.025 in. thickness and up to 24 in. wide.

As shown in the first sketch on page 44, the original method of rolling molten metal directly into strip involved the use of two horizontal rolls, the pool of metal being formed between them and passing, as it solidified, between the two rolls and out as strip. With low melting point pure metals, such as lead and tin, this proves to be a relatively easy undertaking but with high melting point metals or alloys difficulties multiply. Using this two-roll method, the speed of revolution has to be kept low so that the solidified metal, which moves slowly, can pass into the space between the rolls without folding and piling up; thus the rate of production on aluminum strip was but 15 to 50 ft. per min. As the temperature of the metal increased the rolls fire-checked, produced defective surfaces and consequently had short life. When rolling copper, rolls made with shrunk-on sleeves proved satisfactory, but roll life on monel metal and nickel was short and speed of rolling was slow with the result that the metal tended to freeze in the pool. Pure copper strip was produced by this method successfully when the metal was protected at every stage by an atmosphere of carbon monoxide. Roll costs, in the direct rolling of steel, ran 15 to 20 times that in hot strip mills.

While the production of strip of metals having melting points below 2000° F. was successful, the formation of the mushy mixture of solid and liquid, unavoidable in this method of direct rolling, caused serious difficulties. The mushy stage accumulated in the pool just above the junction of the roll faces and then shot through between them, with the result that the liquid phase was squeezed out of it and the product was markedly segregated. In rolling

Reported by
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Superintendent of Research
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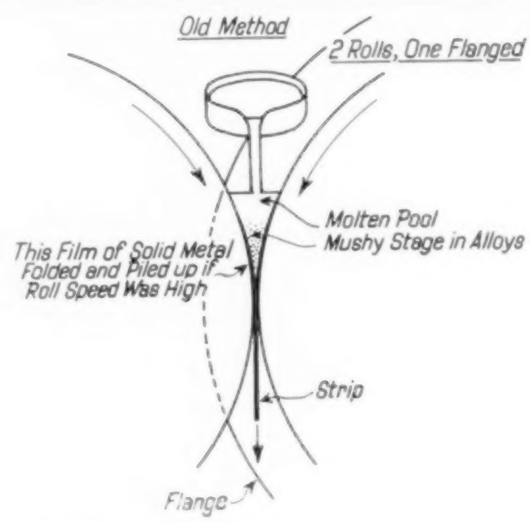
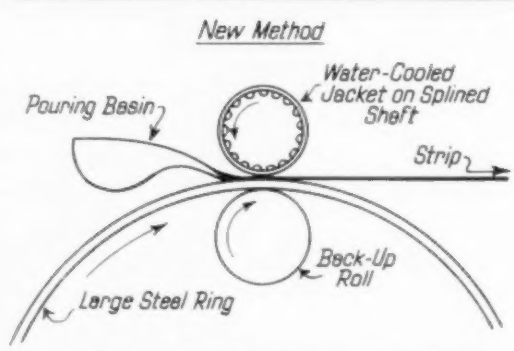
brass, for example, zinc distilled and the strip had a red, high copper surface which was impossible to get rid of. Aside from this defect, which is not always objectionable, brass could be successfully rolled, both brass and aluminum strip having been produced from 3000-lb. and 5000-lb. melts.

Recently Mr. HAZLETT has been producing silicon steel strip, 0.015 in. thick by 3 in. wide, with no more difficulty than when rolling low melting point alloys. His speed, roll and segregation difficulties have been solved by the use of the steel ring as sketched in the second diagram, which can be made as large as desired up to say 20 ft. in diameter. In his new method the molten metal comes in contact with but one chilling surface instead of with two, as in the two-roll process. The ring passes between two small rolls one of which is a backing up roll. The other is a driven and work roll which is internally cooled and consists of a thin, ⅛-in. thick shell shrunk on a splined shaft. At a point 2 in. in advance of the pinch line the molten metal flows through a slit or over a weir onto the surface of the ring which carries it, as it quickly freezes, the short distance to the work roll, and it emerges as strip at the rate, in the installation shown in motion pictures, of 500 ft. per min. Brass strip produced by this method is free of the red stain produced in the older method. Thus there is no liquation, a high speed can be attained, and the rolls have a long life, thanks to easy cooling of the large ring by means of water and by radiation losses.



Old Method (Hazlett Process) Used Two Rolls With Axes Horizontal, but Was Commercial Only for Low Melting Point Metals



New Method Uses Large Moving Ring as a Bottom Mold and a Water-Cooled Shell as a Top "Ironer" to Produce a Chill-Cast Smooth Strip of Metal or Alloy

Speed of production is given as 20 times and roll cost per ton 1 to 2% that of the two-roll type of mill used in direct rolling of copper.

Blisters which have developed on strip produced by the direct rolling process have been traced to the presence of gases adsorbed or combined in some form on the surface of the ring. This has been entirely overcome by preheating the rolls. There has been no trouble from metal sticking to the rolls and the surface of the ring is as good today as when new. The surface of the ring is not wet by the metal which freezes in a matter of 0.02 sec., according to Mr. HAZLETT. Strip may be rolled either by flowing the metal onto the outside or the inside surface of the ring. When using the inside surface it is practical to produce thicknesses up to ⅜ in. Speeds of from 1500 to 2000 ft. per min. appear practical in the new set-up.

Design of Rolls for Rolling Mills

It is hoped that J. R. ADAMS and H. L. WATSON, of The Midvale Co., enlisted a number of new members into the "Anti-Notch Society" by their paper "Some Design Considerations of Forged Steel Rolls". Strong emphasis was placed on the elimination of points of high stress concentration, particularly at the junction of the roll body and journal of hardened and ground rolls. One form was endorsed as advocated by TRINKS and HITCHCOCK, using two fillets connected by a taper. Grooves in the ends of the body or on the journals have been found to cause breakage when, by accident, metal starts to pile up during rolling. Methods were shown whereby a grooved ring can be shrunk on to take the damage and be readily replaced in case of accident. A hole

through the center of rolls permits more efficient heat treatment and enables the roll to be preheated by hot fluid before starting on a run. The loss of strength by removing this much metal from the center is very little, amounting to but 6.75% for a hole with a diameter half that of the roll! Owing to the low stresses on such an internal surface there is no need to finish machine such a bore to a smooth surface, a rough machined bore having been found quite satisfactory.

Not only are sharp fillets discountenanced in roll design but sharp corners as well. A 45° chamfer produces a much stronger corner and minimizes risks of breakage in hardening and in service. As a rule journals ought not to be fully hardened and, since heat treating factors are different for the large body and the relatively small journal, it is an unfortunate circumstance that rolls are sometimes designed with journals to be used as bearing surfaces which require hardening.

The type of stressing is different in two-high roll stands, in four-high housings, and in cluster mills. Rolls in two-high mills are loaded like a beam supported at both ends. Work rolls in four-high and cluster mills are loaded by compression between the back-up rolls and the metal being rolled. Such work rolls should be kept as small in diameter as possible. The limiting factors, as the rolls become smaller in diameter, are lateral deflection, compressive stress set up in the cross-section of the body, and the transmitted torque. Of these limiting factors the compressive stress is usually much the highest.

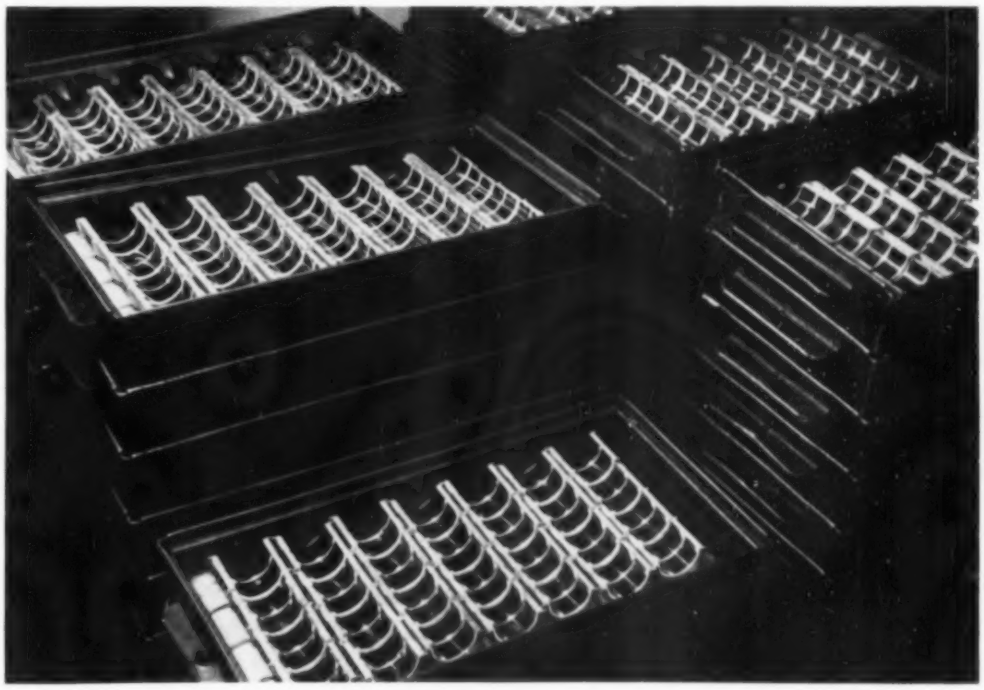
Stresses in the bore of rolls were calculated from a formula which gives a minimum stress range, compression to tension, of 34,000 psi. for a 3-in. bore in a 20-in. roll. For metallurgical reasons a 4-in. bore is used in a 20-in. roll, which raises the stress range to 36,000 psi., but this is found to be quite safe.

Small wonder that points of stress concentration should be strongly emphasized in masses of steel hardened to from 95 to 105 scleroscope! Perhaps no more trying job exists in all the art of heat treating.

Influence of Crystal Size on Bearing Life

By varying the rate of cooling of a cast bearing metal containing 76% Pb, 15% Sb and 9% Sn, John R. Connelly of Lehigh University produced samples having different grain sizes which he used in his study of "The Influence of Crystal Size on the Wear Properties of a High Lead Bearing Alloy". Professor Connelly found wear, in his experimental machine, to be produced in three stages: *(a)* A preliminary stage of decreasing rate of wear called "unlubricated wear" by the author, *(b)* a second stage of constant rate of wear referred to as "lubricated wear", and *(c)* a cessation of increase in rate. Lubricated wear was found to decrease with decrease in size of the crystals although there was a maximum in the curve of crystal size vs. wear which was not satisfactorily accounted for. Since the various crystal sizes were produced by various rates of cooling of the molten metal, it seems possible that this maximum may represent the presence of a phase not present in the product of either faster or slower coolings. The author found confirmation of his results in the fact that the motor industry at present produces bearing inserts having crystals with a linear dimension of the order of 0.001 in., which size gave the lowest wear in his tests.

Finished Bearings Photographed by Van Fisher at Cleveland Graphite Bronze Co.



Analysis of experiments on screw-driven testing machines shows that the tensile specimen is loaded at a continually varying and increasing rate, despite constant screw speed, but that the yield point of steel is not very sensitive to these normal variations

Crosshead Speed Versus Rate of Strain

In his article in Metal Progress for June 1939, Paul D. Ffield calls attention to the desirability of definite control of speed in tensile testing, and shows some of the inconsistencies in the specifications of the American Society for Testing Materials (and many other specifying agencies).

At the present time Committee A-1 on Steel of the A.S.T.M., through Subcommittee XIII on Methods of Physical Testing of which the writer is chairman, is actively and attentively studying the problems involved. Already it is possible to clear up some of the questions raised in Mr. Ffield's article.

In its 1937 report the A.S.T.M. Research Committee on the Yield Point of Structural Steel pointed out that the value found for the yield point of a given steel increased as the pulling speed increased. It recommended that the steel specifications of Committee A-1 should limit the pulling speed, and suggested that for this purpose "rate of loading" or "rate of straining" would be better than the commonly used "free running crosshead speed". As a result of these recommendations the above-mentioned Subcommittee XIII began a study of the question.

In the hydraulic testing machine manipulation of the valve gives accurate and flexible control of the rate of loading and, if a pacing dial is fitted, the rate of loading can be held to any desired value. A screw-driven machine offers no opportunity for such control; three or four gear settings are available, providing as many definite crosshead speeds and once set for one of these, the crosshead travels uniformly and the operator can do nothing about it. There is, in fact, no simple way of measuring the rate of loading at any given instant.

When the relation between crosshead speed and rate of loading is studied, the relation shown in the first curve sheet is obtained. With the machine running with a constant crosshead speed the rate of loading varies throughout the test, increasing as the load increases, as shown by the upward trends in Curves *A* and *B*. These curves are taken from a 200,000-lb. Olsen screw-driven machine. Rate of straining on the 2-in. gage length can be computed from the figures for rate of loading.

For example, a loading rate of 1200 lb. per sec. corresponds to 6000 psi. per sec., or 360,000 psi. per min. With 30,000,000 psi. as the modulus of elasticity, this rate of loading strains the specimen at the rate of $360{,}000 \div 30{,}000{,}000 = 1.2\%$ per min., or 0.024 in. per min. over the 2-in. gage length.

Curve *A* shows that with a crosshead speed of 0.40 in. per min. this rate of loading and

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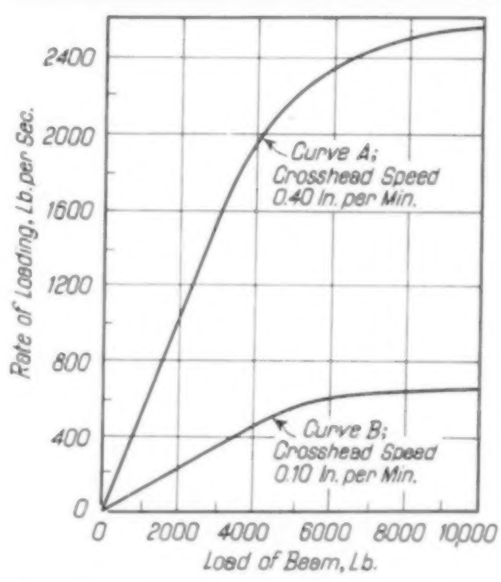
straining will be developed with a load of 2300 lb. on the beam. Under these conditions the crosshead speed is 16.6 times the speed with which the gage points are separating. Curve *A* also shows that with this same rate of crosshead travel (0.40 in. per min.) the rate of loading increases with the load, and at a load of 6300 lb. the rate of loading is doubled, having the value of 2400 lb. per sec., which gives a rate of straining of 0.048 in. per min. on the 2-in. gage length. At this loading the crosshead travels only 8.3 as fast as the gage points separate, instead of 16.6 times as fast, as it did in the earlier stage of the loading.

These ratios between crosshead travel and rate of straining are generally typical of screw-driven machines with steel test specimens 0.5 in. diameter, 2-in. gage length, held in threaded or shoulder grips. With 8-in. specimens of plate tested with wedge grips the difference between crosshead travel and rate of straining is considerably larger. Supporting evidence is given by a number of experiments made for Subcommittee XIII and by the results reported by the Research Committee on Yield Point of Structural Steel.

When a tensile test specimen is pulled in a screw-driven machine, it is evident that as the load comes on, the slack in the machine is taken up, the specimen is bedded down into the grips, and as the load increases the spring in the machine is taken out, all of which represents travel of the crosshead in addition to that required for the straining of the specimen.

For the hydraulic machines the information is not so extensive. Mr. FFIELD in his article gives a table which purports to show the rate of crosshead travel in relation to the rate of loading and says that this is "calculated from the loading rate and elastic modulus for 0.505-in. standard test bar, 2-in. gage length". It is not clear how the calculation has been carried out, for a loading rate of 1000 lb. per min. on a 2-in. gage length with an elastic modulus of 10,000,000 psi. gives a rate of separation of the gage points of 0.00100 in. per min. Mr. FFIELD's table shows for these conditions a "crosshead speed" of 0.00112 in. per min. This same relation is shown throughout the table, giving for all rates of loading and all materials a crosshead speed 1.12 times the rate of separation of the gage points. This 12% difference between crosshead speed and rate of straining seems to make a very small allowance for the bedding of the specimen in the grips and the spring of the shackles. It would be interesting to know how this relation between crosshead speed and rate of strain was obtained and whether there is any experimental evidence to show that the relation is approximately uniform for all loads.

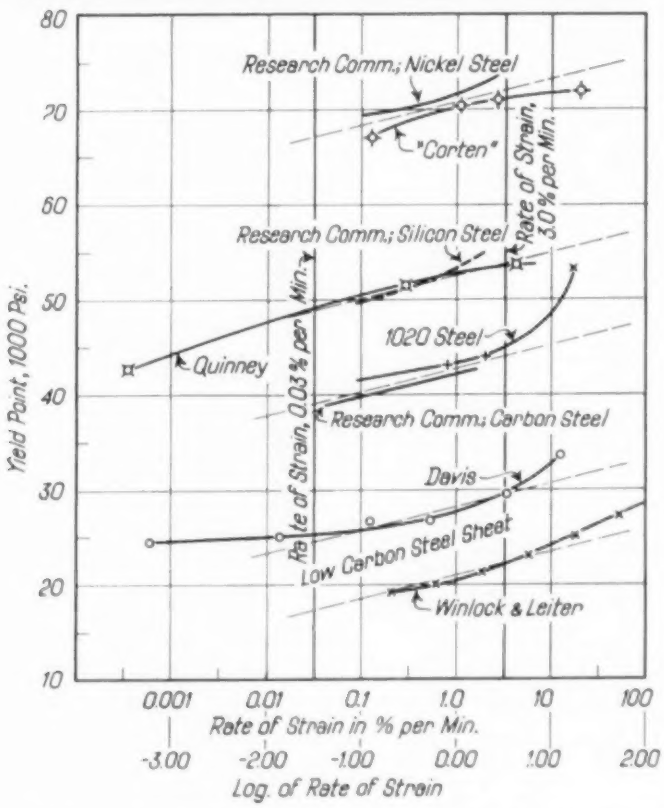


Experiments on a 200,000-Lb., Screw-Driven, Tensile Testing Machine to Determine the Relation Between Load and Rate of Loading for Various Crosshead Speeds

Control for Hydraulic Machine

Mr. FFIELD's article ends with a plea to the bodies writing specifications to set up standard rates of strain or stress for use in controlling test machine speeds, to which he adds the statement that either of these can be controlled mechanically. Evidently he had in mind the hydraulic machine, for the fallacy of this latter statement has been shown as far as the screw-driven machine is concerned. A choice of any one of four or five gear settings is available, and any one gives its own constant rate of crosshead travel when the machine is running free, but the operator has no control over any variations in rate of straining (loading) which may take place while the load is being applied. The curves already discussed make it clear that unless such a series of calibration curves is available, it is not possible to determine the rate of straining at which the yield point occurs. It is not difficult to measure, with a stop watch, the time required to go from one load to another. This gives the *average* rate of loading over the observed range of load, but unless the machine has been calibrated, this tells nothing about the *instantaneous* speed at the yield point.

The value found for yield point of ferrous metals is affected by the pulling speed of the machine, and increases as the speed increases. Undoubtedly the controlling factor in this effect is the instantaneous speed at which the yield point is passed, and not the average speed over a load range before the yield point is reached. There is no way of measuring this instantaneous rate of straining (loading). For this reason it seems desirable for screw-driven machines to limit the rate of pulling by the speed of the free-running crosshead.



Various Investigations Show That Yield Point of Steels Increases Slightly as Rate of Strain Increases

This may at first seem illogical in view of what has been said above as to the variable relation between crosshead speed and rate of loading. It is, however, based on what seem to be very good reasons.

In the case of the screw-driven machine from which Curves *A* and *B* are taken, it is evident that for a specified yield point value a given crosshead speed will correspond to a definite rate of loading. For example, a specified yield point of 30,000 psi. means a load on the beam of 6000 lb. at yield. If the free running crosshead speed is 0.10 in. per min., the rate of loading is shown by Curve *B* to be 600 lb. per sec., or a rate of straining of 0.012 in. per min. in the 2-in. gage length, or 0.6% per min. Similarly, for any specified yield point value a given crosshead speed gives a definite rate of loading and hence a definite rate of straining.

The characteristics of various machines may differ somewhat, so that for the same crosshead speed and same yield point value there may be a slight difference in rate of loading. The effect of such differences as may occur between two screw-driven machines is not sufficient to be of practical importance; it is of the same order as the difference in yield point value to be expected between two lots of reputedly similar material.

The effect of rate of straining on the yield point value is indicated by the second diagram, based on tests on a number of different steels by several observers. Without going into details, it may be noted that for rates of straining in the range between the vertical lines, that is from 0.03% to 3% per minute, which covers the extreme range likely to be encountered in acceptance specification testing, a multiplication of the rate of straining by 10 increases the yield point value by only about 2500 psi. This indicates that the rate of straining can vary through a fairly wide range without having any important practical effect on the value found for the yield point of a given material.

The foregoing describes some of the territory explored by Subcommittee XIII in the attempt to develop proper requirements for testing machine speeds. Other work under way has to do with the correlation of loading speeds of hydraulic machines with rate of strain in screw-driven machines. In the latter, control of rate of straining is impracticable, and measurement of instantaneous rate of loading is practically impossible. In the hydraulic machine the conditions are reversed. It is not easy to maintain a known, uniform crosshead speed, but is easy to vary the rate of loading. By means of the pacing dial the rate of loading can be held to any desired value.

Correlation Necessary

The title of Mr. Field's article asks, "What is Wanted — Crosshead Speed or Rate of Strain?" The answer seems to be: "Crosshead speed for screw-driven machines, and rate of strain (load) for hydraulic machines, with proper correlation between the two."

Supplementing the voluminous data in the 1935 edition of "The Book of Stainless Steels", Mr. Smith gives some notes on more recent modifications of the high chromium steels in the form of castings, and some new data on castings containing less than 5% chromium

Chromium Steel Castings

CHROMIUM is a powerful alloy. When added to steel or iron, it confers on the metal certain definite qualities, such as resistance to oxidation, or corrosion, or wear, or growth, or abrasion, and imparts air hardening and depth hardening properties. Numerous compositions, low in carbon, are in use today containing chromium with, or without, other alloys. This paper will deal with some of the newer chemical combinations, and new developments with old compositions, used in cast form. No attempt will be made to include the uses and properties of similar analyses in various wrought shapes. Chromium cast irons were also treated at length in METAL PROGRESS, in November 1938.

Base Metal — In making alloy steel it is essential to have a good base metal. Especially in case of low alloy steels, it is necessary to have the bath in proper condition before the alloys are added.

During the past year, one steel foundry found an occasional heat of low alloy steel which was deficient in ductility, and in order to locate the difficulty, all test bars with low ductility were saved, as were all bars showing especially good ductility. Examination showed that all the satisfactory steel contained round inclusions similar to those shown in the first micro, page 50, while the low ductility bars always contained some stringy, intergranular inclusions. The inclusions were almost identical with those described in 1932 by SIMS and LILLIEQVIST in *Transactions* of the American Institute of Mining and Metallurgical Engineers, Iron and Steel Division, vol. 100, page 154. By making a preliminary furnace test for "over reduced" metal, and following with necessary additions, it was simple to eliminate the stringy inclusions consistently, and to produce uniformly ductile alloyed, as well as carbon, heats.

Low Chromium Steels

Chromium Under 2% — Such steels were the first American alloy steels. Beginning in 1869 and for over 50 years the Chrome Steel Works in Brooklyn (now defunct) manufactured chromium steel castings and forging ingots. The first product contained about 0.80% chromium, and was made by the crucible melting of wrought iron, own scrap, chrome iron ore and carbon, fluxed with sodium carbonate. Such castings were much used for rock crusher parts and grinding balls. A historical account of this firm and of the later production of ferrochrome and high chromium castings was given by FREDERICK M. BECKET before the Iron & Steel Division dinner of the A.I.M.E. in 1928.

One of the most interesting developments during the past few years has been the great increase in production of steels containing approximately 1% chromium. These have been known for many years, especially in the larger foundries, but recently a surprising tonnage is being cast in many of the smaller foundries. They are being used where resistance to

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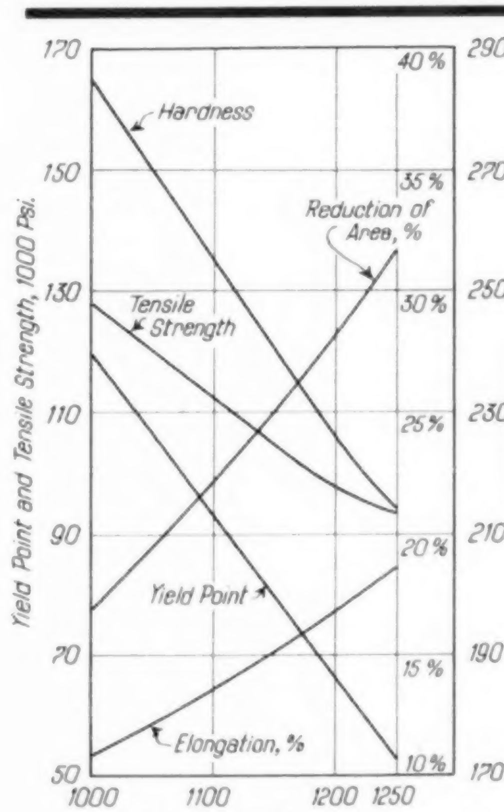
Harmless Round Inclusions in Chromium Steel Castings, and Stringy Inclusions at Grain Boundaries That Cause Low Ductility in the Tension Test. Unetched; 200×

wear and abrasion is important, and where costs must be kept to a very minimum. Melting procedure is easy, and simple heat treatments give the desired results. As comparatively little has been published on these low chromium steel castings, it seems best to give actual recent instances where these steels have given good results in service. These values do not represent the maximum obtainable, but results readily reached by the average foundry with average equipment.

The first curve sheet is drawn from numerous commercial heats. Melting procedure is the same as that for carbon steels, except that ferrochromium is added in the furnace about 10 min. before tapping; recovery is usually about 90%.

An especially valuable property of 1% chromium steel is its ability to withstand differential hardening. For example, a wheel may be cast of this composition, generally with a small amount of vanadium or molybdenum; suitable heat treatment softens the metal in the center, thus giving excellent resistance to shock, while the rim can be quenched to at least 400 Brinell for resistance to wear and abrasion.

A practical instance of using a good combination of other alloys with chromium, to obtain specific results, was noted recently. Certain steel castings were subject to extremely severe wear and abrasion, particularly from sand, and were also exposed to heavy shocks. An S.A.E. 3140 steel base was used, plus small amounts of molybdenum and vanadium, the final composition being: Carbon 0.40%, manganese 0.70%, nickel 1.25%, chromium 0.70%, molybdenum 0.15% and vanadium 0.06%. These castings are annealed at 1650° F., then normalized at 1525° F. and



Properties of 1% Chromium Steel Castings After Air Cooling From 1650° F. and Drawing at Various Temperatures. Approximate composition: 0.95% Cr, 0.35% C, 0.30% Si, 0.65% Mn

not drawn. Brinell hardness averaged about 300. These castings are standing up well in service, giving much longer life than the material formerly used.

In another case, sand abrasion and impact were causing rapid failure, but very good service is now being obtained from S.A.E. 4150 castings, containing 1.0% chromium, 0.20% molybdenum, and 0.50% carbon. Heat treatment consists of an anneal at 1650° F., oil quench from 1550° F., and draw at 700° F. Brinell hardness runs about 450; the structure of these castings is martensitic.

A rather inexpensive steel for service where resistance to both abrasion and impact are necessary is a combination of the well-known pearlitic manganese steel and the 1% chromium steel. As might be expected, this combination of manganese 1.50%, chromium 1.00% gives excellent hardness combined with toughness, and is particularly suitable for castings subjected to wear and abrasion.

3% Chromium Steels — Some years ago, a hundred tons or so of openhearth steel containing 3% chromium and 0.30% carbon was rolled into various shapes, and these were distributed where they would be subjected to very severe service. It is now apparent that they were extraordinarily resistant to abrasion. Numerous foundrymen started to make this 3% chromium steel, and today it is being used for many applications, generally where resistance to abrasion is the governing factor. In physical properties, it is intermediate between the 1% and the 4 to 6% chromium steels. Like the others, it often contains up to 0.50% molybdenum for toughness and for prevention of embrittlement, or small amounts of vanadium for toughness. Manganese is usually run on the low side, say from 0.40% to 0.60%, in order to prevent undue formation of martensite.

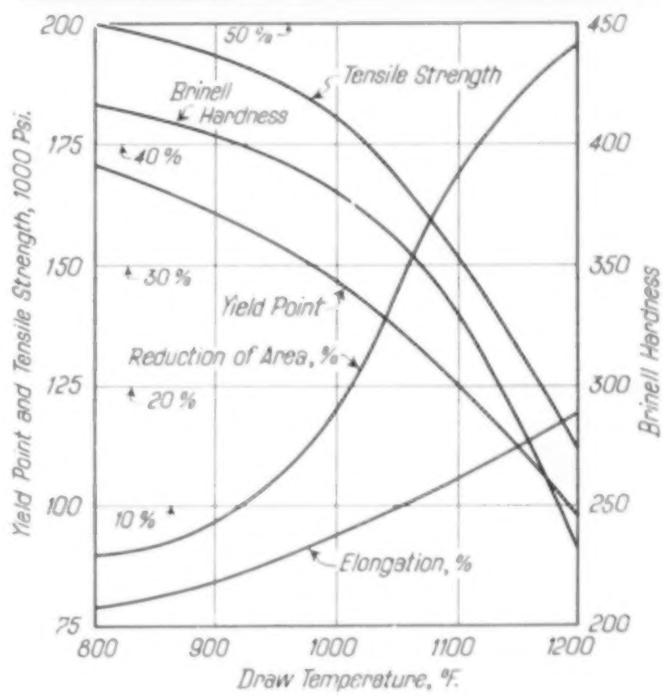
In common with other air hardening chromium steels, a wide range of physical properties can be obtained by simple heat treatment, as is indicated in the curves in the second diagram derived from a good many individual heats. The difference in structure produced by a draw at 800° F. after air quench, and a draw at 1100° F. is seen in the micros on page 52. By varying the carbon or heat treatment, a great variety of desirable properties may be obtained.

Machinability of these castings is excellent in the annealed state.

In heavy sections, an extremely uniform hardness is maintained in the 3% chromium steels. For high hardness, either a differential quench or torch hardening is available.

This steel is now being widely used for guides, crusher parts, rolls, rails and wheels — in fact wherever resistance to wear, abrasion and mild corrosion is desired.

4 to 6% Chromium steel castings are almost too well known to need mention, although most of the published physical properties deal with the rolled product. Castings of this composition are most frequently used in connection with 4 to 6% chromium seamless tubes, and in similar applications. Such steels combine strength with excellent resistance to abrasion and erosion, and considerable resistance to high temperature corrosion.



Physical Properties of 3% Cr Steels, Air Cooled From 1650° F. and Drawn as Indicated. Note the especially good combination of properties after a 1050° draw. Approximate composition: 2.8% Cr, 0.55% Mn, 0.35% C, 0.40% Si

Usually either 0.50% molybdenum or 1.0% tungsten is used to prevent temper embrittlement. In some instances silicon has been raised to 1.50% or higher, with the idea of increasing the resistance to scaling. This result is doubtless accomplished, but when silicon becomes much higher than 1.50% there may be a decided tendency towards brittle castings; silicon is usually held well under 1.00%. Many producers prefer to run carbon on the low side with

chromium on the higher, because they thus obtain castings which air harden to a lesser degree and have greater resistance to corrosion. Relatively large amounts of aluminum or titanium or columbium have sometimes been added to suppress the air hardening characteristics. This end may be attained without difficulty, but so far as the author is aware, suppression of air hardening is accompanied by loss of ductility as measured by impact values.

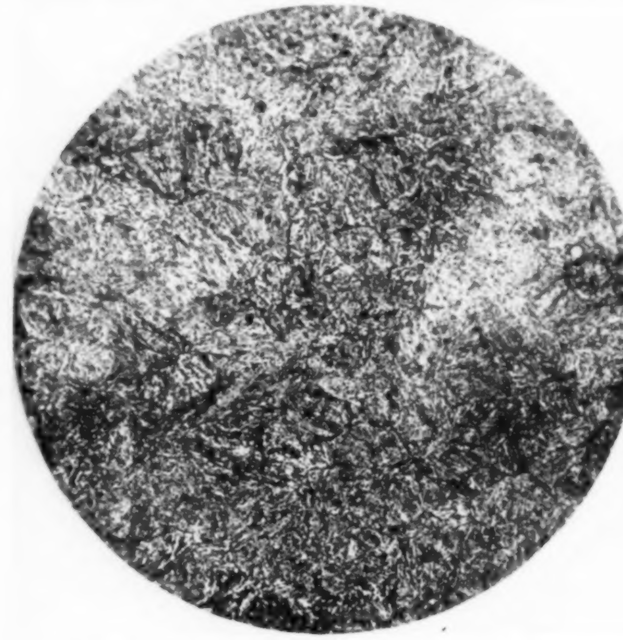
As the 4 to 6% chromium steels are decidedly air hardening, heat treatment is important. This generally consists of normalizing at 1650° F. with a draw at approximately 1200° F. Double normalizing raises the properties.

Air hardening has caused some difficulty when the risers were cut off the castings. Small cracks would appear which might readily enlarge when the castings went into service. This difficulty has been eliminated in different ways. One method has been to anneal the castings before cutting. Another way is to cut off the risers while the castings are still warm — approximately 500° F. Still another way is to leave a raised pad between the riser and casting proper; the riser is then cut off by oxyacetylene flame as usual, and if any small cracks are produced they are contained in the raised pad and are later machined or ground off.

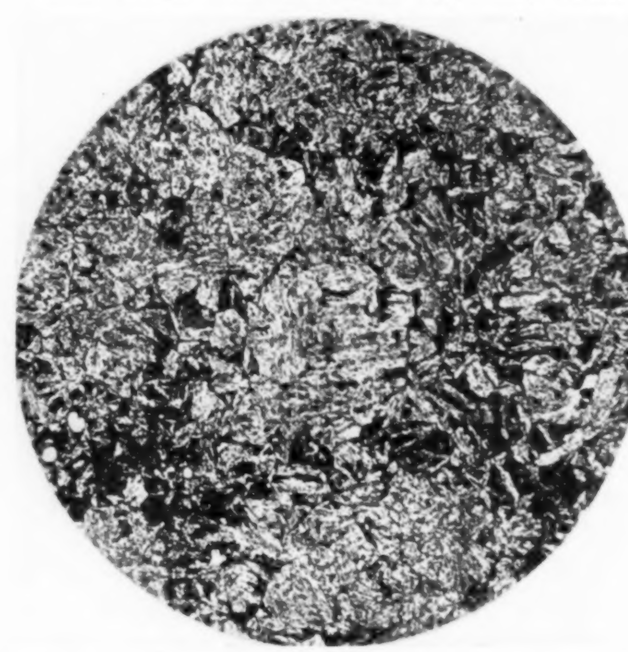
The 4 to 6% chromium steels have a tendency to absorb gas which may be given off when the castings solidify, producing pinholes which appear after machining. For this reason, it is desirable to use every precaution in melting these steels, to have the molds at least skin dried, using molding sand sufficiently open to vent the evolved gas. Moisture in the sand should be on the low side.

Avoid any moisture in the furnace; raw materials should, of course, be dry. It is also important to avoid reduction of silicon from the slag. Residual silicon should be ored down to the lowest practical limit to eliminate all gas possible. In finishing the heat, ferromanganese should be added first, and the ferrosilicon just before tapping.

Castings of this steel are very widely used, particularly in the oil industry for such things as return bends. Service properties are intermediate between those of carbon steels and highly alloyed heat resistant steels. They have proven highly satisfactory and reliable in appropriate service, and are often used where obsolescence would scrap the equipment before more expensive stainless steels would fail.



Variation in Microstructure of 3% Chromium Steel, Air Cooled From 1650° F. and Drawn at 800° F. to a Rather Fine Structure and at 1100° F. to a Coarser One. Etched in 5% nital; 250×



Chromium-Nickel Steels

Properties of the various stainless steels are recorded in many trade and technical publications, and assembled in "The Book of Stainless Steels", but it seems of possible interest to mention specific applications or changes in some of the more popular steels. The corrosion resistance of these steels has been very thoroughly covered in a paper by James H. Critchett in *Refiner and Natural Gasoline Manufacturer* for April, 1937.

15% Chromium, 14% Nickel — This rather unusual alloy is giving very good service in

valve stems. Carbon runs about 1%, silicon about 3%.

15% Chromium, 35% nickel is a popular steel for resistance to high temperatures. The author had the opportunity to inspect an installation which had been in continuous service, alternating from room temperature to 1900° F. for three years. The castings appear to be exactly the same as when cast; there is no evidence of scaling or distortion.

18% Chromium, 8% Nickel — Use of this standard combination is expanding steadily. In certain types of service involving corrosion, an addition of 3% molybdenum adds greatly to the life of the castings. One fairly new application would have been considered almost ridiculous a few years ago, and that is for manifolds in heavy duty automobile engines. In spite of the higher cost of stainless, it has proven its economy.

An innovation in the making of stainless steel castings is in the type of final deoxidizer. It has been found that the complex deoxidizers, such as calcium-manganese-silicon, give particularly well broken-up inclusions, with consequent better physical properties.

29% Chromium, 9% Nickel — There has been a strong swing towards the well-known "29-9" composition, to which 1% of molybdenum is sometimes added. Due to the higher proportion of alloys, it is possible to run carbon considerably higher than in 18-8, which makes for very sound castings. Machinability of 29-9 is appreciably better than 18-8, and 29-9 is therefore being used in large tonnages, especially for paper mill work and for heat resistance.

An interesting point in the manufacture of such compositions is the striking effect of pouring temperature on structure. Castings poured at high temperatures have much coarser grain (and less elongation in tensile tests) than those poured at lower temperatures such as 2600° F. The 29-9 composition gives slightly higher strength and lower ductility than cast 18-8. It has remarkable resistance to intergranular corrosion. Hardness as cast is from B-90 to 95.

Special Chromium Steels

21% Chromium — Among the steels used for high temperature service where corrosion is encountered is a 21% chromium, 1% copper analysis.

24% Chromium is a steel coming into increased use on account of its extreme resistance to wear at high temperatures. Typical is following composition: Chromium 24%, tungsten 6.0%, vanadium 0.15%, carbon 2.25% and silicon 0.30%.

29% Chromium — A recent report from Norway states that a modification of the high chromium, high carbon steel is in wide use in that country. This contains chromium 29%, nickel 2.5%, carbon 0.70%, silicon 0.70%, molybdenum 1.0%, with either titanium or nitrogen as a grain refiner. Tensile strength is reported from 60,000 to 100,000 psi., Rockwell hardness C-29 to 35. Further valuable information on chromium irons and steels may be had in this report by JOHN SISSENER, "Foundry Work on High Chromium-Iron Castings", in METAL PROGRESS for October 1937.

Chromium in Manganese Steel Castings — An interesting recent development has been the addition of chromium to Hadfield's manganese steel. Where the 12 to 14% manganese steels have insufficient opportunity to work harden in service, they wear out rapidly. To give the alloy more intrinsic hardness, from 1 to 3% of chromium has been added. It hardens the manganese steel very definitely and reduces wear due to abrasion, but does not prevent the soft austenitic structure from changing to hard martensite when it is battered or struck hard enough to cause a little plastic flow. It has also been found that additions of chromium also raise the yield point of the manganese steel, thereby preventing its flow under steady tensile or compressive loads. The simple addition of, say, 3% chromium to an austenitic manganese steel may give more hardness than needed, and reduce ductility too much; recent practice, therefore, is to drop carbon to 1% and to add copper or nickel from 1 to 2%, with or without molybdenum. The combination of 13% manganese with 3% chromium and the other alloys mentioned gives great promise for extreme resistance to impact and wear of all kinds.

Columbium Additions to the wrought chromium steels and the stainless chromium-nickel steels form very stable carbides which are insoluble in the metal and thus cannot be diffused to the grain boundaries or cause any hardening effects. This is a particularly valuable circumstance when the steels are welded. For similar reasons columbium has been tried in various types of chromium castings. While these are still under observation, it has been stated that columbium reduces the impact strength of the high alloy stainless steels appreciably, but still leaves

sufficient impact resistance to be satisfactory in many types of service.

Where columbium has been added to the lower chromium castings (say, 5% Cr) it has prevented air hardening and increased resistance to oxidation, but has made a drastic reduction in impact values. This undoubtedly is due to the formation of columbium carbides which, in the rolled steels, are so broken up mechanically that the impact values are satisfactory.

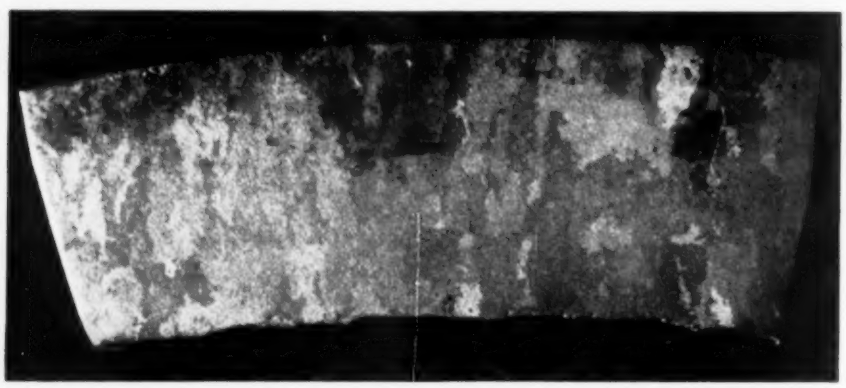
Titanium Additions — The effect of small titanium additions is to tie up carbon in the form of titanium carbides. This prevents air hardening, and lowers the yield point and tensile strength. In the lower chromium ranges the effect of titanium is not yet definitely determined. Present data indicate that the impact values of castings are reduced. In the higher chromium analyses, titanium refines the grain. For this purpose it is usually added in small amounts, about 0.05% or more.

Nitrogen in Chromium Steel Castings — Since the publication of the paper on "Chromium Steels of High Nitrogen Content" by Russell Franks in *Transactions* (1935) there has been a great amount of work on the best amount of nitrogen to use in the various analyses. As pointed out by him, nitrogen reduces very greatly the grain size of the high chromium steels and, to a great extent, prevents grain growth at high temperatures.

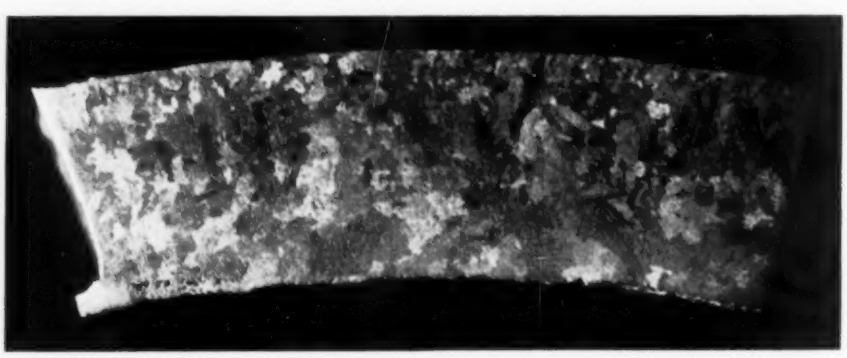
To cite one specific instance, certain castings containing over 20% chromium had a tendency towards porosity, and it was found that the steel containing 0.14% nitrogen was decidedly sounder than a steel identically made, but containing only 0.07% nitrogen. The upper section in the last photograph is of an analysis higher in nitrogen.

In many installations, particularly in the oil fields, use of the high chromium steels has been indicated, but their use has been restricted due to their large grain size and resulting lack of ductility. The use of nitrogen-bearing ferrochromium has practically eliminated this objection, and today there are many castings in use, both plain chromium steels and chromium-nickel steels containing nitrogen.

There has been a slight reduction in the amount of nitrogen considered necessary to give fine grain, and the general tendency at present is to use approximately 0.14 to 0.16% nitrogen in steels containing 26 to 28% chromium.



Increase of Nitrogen in 25% Chromium-Iron Casting From 0.07% (as Shown Below) to 0.14% (as Shown Above) Eliminates Definite Dendritic Structure and Decreases Tendency Toward Porosity. Half size, deep etched



Conclusion

After reading the above notes, all taken from successful applications of chromium steel castings of rather unusual analysis, and by no means posing to be an exhaustive statement of the situation, the reader will realize that metallurgists have come a long way since 1884, when Wm. Henry Greenwood, associate of the Royal School of Mines, wrote so amazingly in his "Steel and Iron, a comprehensive manual":

"Chromium, when alloyed with iron, decreases the fusibility of the metal, and like tungsten is said also to increase the tenacity, malleability and ductility of the steel in which it occurs. Chromium appears to partially replace carbon in steel. The presence of tungsten in steel is said to render it less oxidisable by exposure to ordinary atmospheric conditions, whilst chromium acts exactly in the reverse manner."

Electrolytic Preparation of Iron and Steel Micro-Specimens

P. A. Jacquet and P. Rocquet have recently reported that electrolytic polishing may be substituted for ordinary metallographic polishing of iron and steel with excellent results, and with a very large saving in the time required for the preparation of samples for microscopic examination. The reader should see the reprint from *The Metallurgist* in Metal Progress for December 1939, page 771, and the note on page 756 of the same issue about its successful use for grain size control in heat treating non-ferrous wire.

It is thoroughly obvious to the metallographer that any method resulting in a saving in the time of preparation of specimens would be a great boon, particularly if such a method were readily applicable to the ordinary run of iron and steel samples inspected in industrial laboratories. This present brief paper is an attempt to evaluate the method of Jacquet and Rocquet in order that its usefulness to industry may be appraised. The specimens studied have been selected from the tonnage steels.

It may be said immediately that all of the claims made for the method have been confirmed. The methods used in preparing the specimens are those recommended by the originators and given in the data sheet on page 57; the apparatus is shown in the sketch and is simple and easy to assemble. Briefly, all samples were ground and then rubbed on emery paper to and including the 000 paper, and then polished electrolytically. The recommended electrolyte of acetic anhydride, perchloric acid, and water was used, with temperatures below 30° C. (85° F.). The space between electrode and sample was ¾ to 1 in.; the area of the aluminum cathode was approximately 20 times the surface area of the specimen.

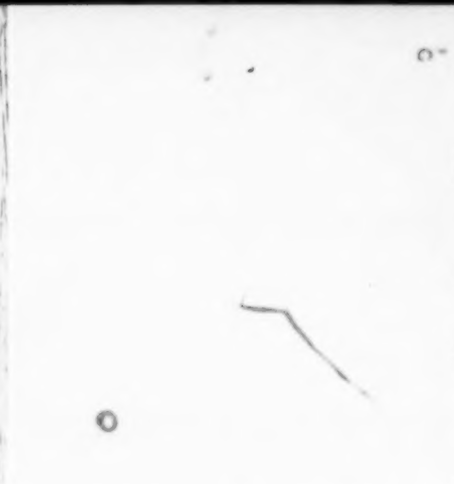
Adjustment of current density appears to be the most important item in technique; at too low a current density, deep and objectionable etching occurs, and at too high a current density gas is evolved at the specimen and causes uneven polishing. Current density is satisfactory when upon changing the cell voltage no appreciable change in current density occurs. Mounting of specimens is unnecessary — organic or synthetic mounting materials such as bakelite should not be used owing to the danger in the reaction between such materials and perchloric acid. Details of electrolyte composition, current density, cathode material, and temperature are given in the data sheet. We find that electrolytic polishing of steel under these conditions requires about 10 min.

Surfaces prepared in this manner, after etching with ordinary reagents, are quite satisfactory for microscopic examination and photography in the whole range from low to very high magnification. Compared to the difficulty of polishing on wheels, very little skill is required for the preparation of satisfactory surfaces. These surfaces do show some undulation, but this is on too gross a scale to be trou-

By G. E. Pellissier, Jr., Harold Markus, and Robert F. Mehl

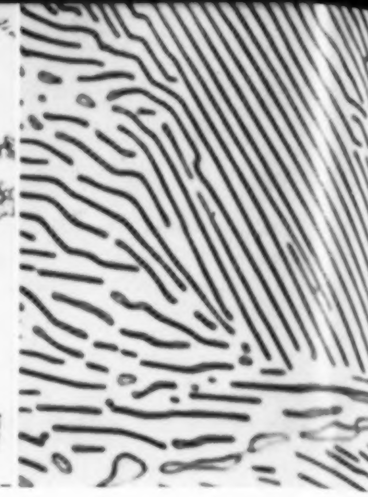
Respectively, International Nickel Co. Fellow in Metallurgy, Research Assistant in Metals Research Laboratory, and Head of the Department of Metallurgy, Carnegie Institute of Technology, Pittsburgh

Scratches From 000 Paper on Steel Specimen (100X)



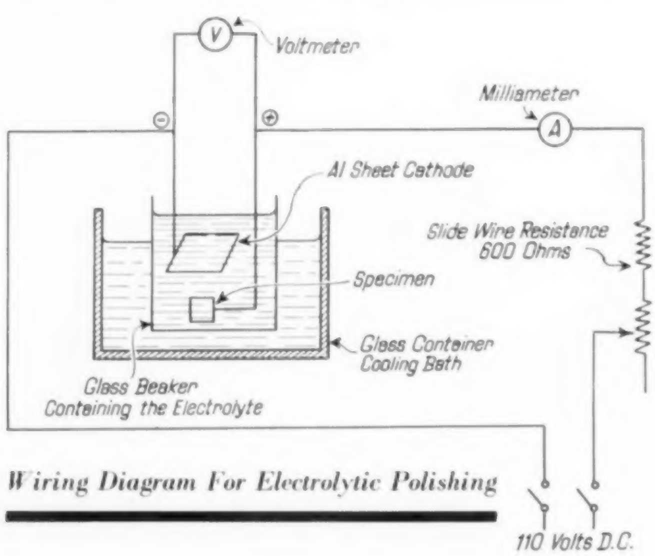
Inclusions and Quenching Crack (2000X) Unetched

Hot Rolled 0.30% C Steel (1000X) Electro-Polished, Nital Etched



Pearlite (2500X) Electro-Polished and Electro-Etched

blesome even at magnifications below 100 diameters. Since electrolysis seems to remove protruding ridges between the 000 scratches, it may appear surprising that specimens may be more readily polished to an edge than with the ordinary polishing procedure. Flat surfaces on large specimens are much more readily pre-



Wiring Diagram For Electrolytic Polishing

pared. The electrolytic method appears to have special advantages for the study of inclusions, for these are obviously not *ground* flat during electrolytic polishing, but retain the same shape as within the body of the steel.

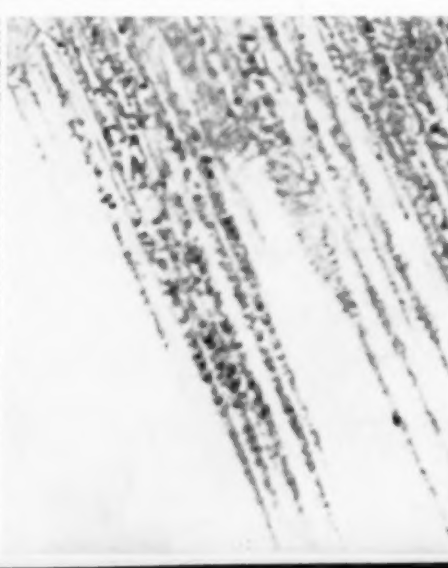
The first photomicrograph shows the surface of a typical specimen at 100 diameters after finishing on 000 emery paper; the second shows the same specimen at 2500 diameters after electrolytic polishing but before etching. No scratches are evident on this photograph nor on any that have been prepared. The series of photographs, even those at 2500 diameters, shows also that the definition is excellent and — this is an important point even for the relatively hard steels — that there is no evidence of distortion of the structure. Photomicrographs of hypo-eutectoid and hyper-eutectoid steels appear equally as satisfactory as the rest even though these alloys are heterogeneous on a grosser scale. Those of cold worked stainless steel appear to be particularly satisfactory. Inclusions appear in the sample not etched and show the absence of fragmentation or pitting at the inclusions; a quenching crack is shown clearly. It appears likely that the lack of distortion or flow which is a characteristic of this method is an especially favorable factor in its use in the study of cracks generally. Likewise the examination of freshly quenched martensite is expedited, for there is no danger of tempering the structure by frictional heat.

Although this study is by no means complete, it seems certain that the method of electrolytic polishing is one which will become of great importance to the metallographer.

Martensite (500X) *Bainite (2500X) Transformed 30 Sec. at 850° F.*
Eutectoid Steel, Electro-Polished, Picral Etched

Armco Iron (500X) Electro-Polished, Nital Etched

Strained 18-8 Stainless (100X) Electro-Polished, 10% Oxalic Acid Etched



Electrolytic Polishing of Metals

Compiled by G. E. Pellissier, Jr., Harold Markus, and Robert F. Mehl

Metal	Solution	C.D.*	Voltage	Temp. °C.	Time Min.	Remarks	Reference
All carbon steels, martensitic, pearlitic, and sorbitic; Armco and white cast iron; 3% silicon steel	Acetic anhydride, 765 cc. Perchloric acid, 185 cc. sp.gr. 1.61 (65%) Distilled water, 50 cc. 0.5% Al	4 to 6	50†	<30	4 to 5	Prepare solution 24 hr. before using. Use moderate agitation. Al increases viscosity which permits more vigorous agitation and current density of 3. Can use at current density of 10 for austenitic steels. Prepare samples to 000 paper. Fe or Al cathode.	15
Austenitic steels‡	Acetic anhydride, Perchloric acid (65%) 2 parts to 1 part	6	50†	<30	4 to 5	Same as above.	15
Iron and silicon-iron	Orthophosphoric acid sp.gr. 1.316	0.6	0.75 to 2.0			Iron cathode.	13
Tin	Perchloric acid (sp.gr. 1.61), 194 cc. Acetic anhydride, 806 cc.	9 to 15	25 to 40†	15 to 22	8 to 10	Stir solution if length of electrolysis is over 10 min. Polish to 000 paper. Tin cathode. Electrodes 2 cm. apart.	12
Copper‡	Orthophosphoric acid sp.gr. 1.3 to 1.4	0.65 to 0.75	2	Room	>5	Polish to 0000. Copper cathode. Electrodes 2.2 cm. apart.	7
Copper‡	Pyrophosphoric acid 530 g. per l.	8 to 10	1.6 to 2.0	15 to 22	10 to 15	Polish to 00000 paper. Copper cathode.	5
Cobalt	Orthophosphoric acid sp.gr. 1.35		1.2			Rough metallographic polish. Cobalt cathode.	11
Aluminum‡	Perchloric acid (sp.gr. 1.48) Acetic anhydride, 2 parts to 7 parts	3.0 to 5.0	50 to 100†	<50	15	Allow 4 to 5 g. per l. to enter solution. Polish to 000 paper. Aluminum cathode.	8
Zinc‡	Potassium hydroxide 25% solution	16	6	Room	15	0000 paper. Solution agitated by air or nitrogen. Copper cathode. Electrodes 2.5 to 15 mm. apart.	10
Lead	Acetic acid, 650 to 750 cc. Perchloric acid, 350 to 250 cc.	1 to 2			3 to 5	0000 paper, horizontal anode. Use current density of 20 to 25 for 1 to 2 min. to remove flowed layer. Copper cathode.	5
Pb-Sn alloy	Same as above	2					5
Tin + 3% Sb	Same as for tin, above	9 to 15	25 to 40†	15 to 22	8 to 10	Same as for tin, above.	12
Copper + 3.2% Co Copper + 2.4% Fe	Orthophosphoric acid sp.gr. 1.35	0.07	2		5 to 10	Polish to 000 paper. Copper cathode. Electrodes horizontal and ½ in. apart.	14
Brass, 70-30,‡ (1 constituent)	Orthophosphoric acid 430 g. per l.	13 to 15	1.9				5
66.7-33.3 Brass‡	Orthophosphoric acid 990 g. per l.	2.5 to 3					5
Two-constituent 60-40 brass ‡	Pyrophosphoric acid 530 g. per l.	9 to 11	1.9				5
Aluminum bronze; Leaded bronze (85 Cu, 10 Sn, 3 Zn, 2 Pb)	Orthophosphoric acid 990 g. per l.	1 to 2					5
Phosphor bronze, silicon bronze, monel, nichrome, nickel, and ‡ metals	Methyl alcohol (abs.), Nitric acid (conc.), 2 parts to 1 part		40 to 50†	20 to 30	Seconds	Cathode of stainless steel cloth in bottom of dish. Distance between electrodes ½ to 1 in.	17

*Current density in amperes per square decimeter. †External applied voltage. ‡See last item in table.

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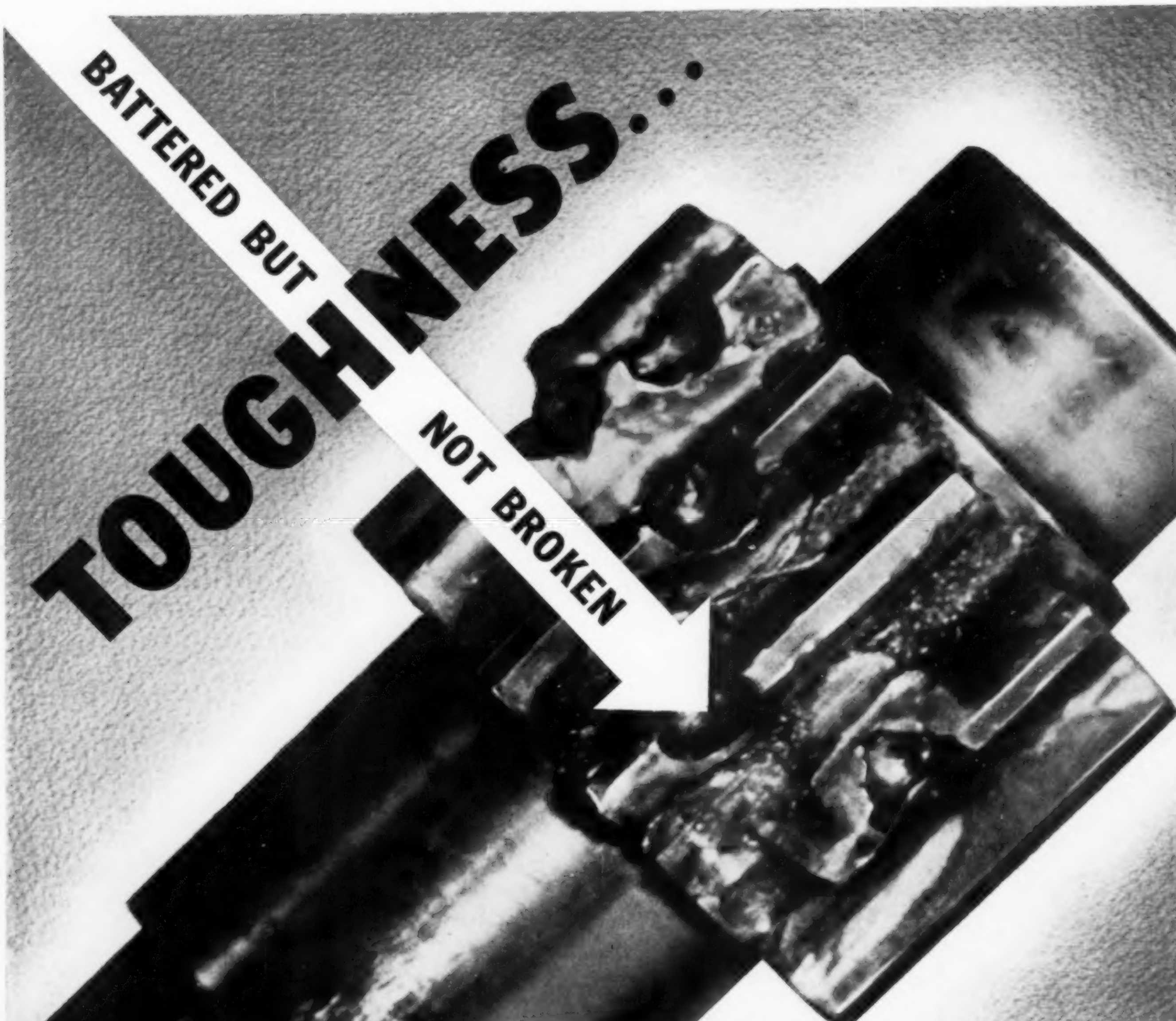


Twelve years ago engineers of Automatic Transportation Co., Chicago, specified SAE 3135 Nickel-toughened steel for pinions in their industrial trucks. After 12 years' service, this Nickel alloyed material retained ductility and toughness to deform rather than break when ball bearings fell into the teeth.

WHAT you need for dependable service — at lowest cost per year — is a tough material combining ample strength and hardness with unusually high ductility. A significant example of such a metal, which deforms rather than breaks, is this pinion pictured above. Balls from a shaft bearing of an industrial truck escaped from their race and fell into the teeth of this pinion gear.

After twelve years' service, this pinion — forged from heat treated SAE 3135 Nickel chromium steel — was still strong enough to stand up under crushing stress. Despite their ductility, these teeth proved too hard for redressing. Make sure of metals which will be strong and tough after twelve years' economical service. Specify Nickel alloyed materials for all vital parts which must resist stress and wear.

THE INTERNATIONAL NICKEL COMPANY, INC., 67 WALL ST., NEW YORK, N. Y.

Improvements in telephone cables have packed 2121 circuits, pairs of wires, into a space where 52 were carried in the early days of the industry. Power cables can now carry underground almost as high a voltage as the overhead transmission systems

Important Developments in Electrical Cable

IN AN INTERESTING article in last November's METAL PROGRESS, Messrs. SCHUMACHER and ELLIS described some important development work on lead alloys and their extrusion into cable sheathing. He might have gone on and mentioned the fact that communications engineers are now able to pack many more complete circuits into a single 2½-in. cable than heretofore, and that an entirely new type called the co-axial cable is now in service on the main long distance telephone trunk line between New York and Philadelphia.

Other very interesting improvements have been made on power cables, not only for overhead but for underground and underwater transmission lines. The latter has required progress in all types of insulation and covering, and has resulted in at least one underground line in France carrying power at 220,000 volts. Only a few years ago such a line would have required high towers and long strings of suspended insulators.

While most of the changes have had to do with insulating media, mechanical devices for manufacturing, and study of the electrical and magnetic phenomena, the metallurgical aspects of the problem warrant a brief description in this journal.

By Carleton Cleveland
Highland Park, Ill.

Telephone Cables

The story of the telephone cable is one of continually decreasing size of conductor and thickness of insulation. In 1887 the situation was "standardized" at No. 18 B & S gage copper wire, (0.040 in. diameter) covered with two wrappings of cotton; thus 52 pairs could be carried in a 2-in. cable sheath. By 1891 paper tape made of Manila rope fiber was used for insulation, cutting the electrostatic capacity of the cable in half. As more efficient transmitters, receivers, and other apparatus were developed, the need for large conductors diminished, and thread-like 26-gage wire (0.016 in.) made its debut in 1928. Winding this wire with paper tape ¼ in. wide by 0.0025 in. thick enabled no less than 1818 pairs to be packed in a 2⅝-in. cable (outside diameter).

Research and experimentation still continued. By reducing the wire gage two more numbers, by paying the greatest attention to surface continuity and cleanliness, by embedding this wire in the center of a film of paper pulp, ¼ in. wide, and then spinning this gossamer around the wire, the insulation thickness has been cut 0.0003 in. and today 2121 pairs of wires are squeezed into the same 2⅝-in. sheath.

Even such close packing has its limits. Hence the co-axial cable. Originated in the course of telephone development, it is suitable for transmission of broad frequency bands, and

the long waves of television (although the latter is still in its beginning).

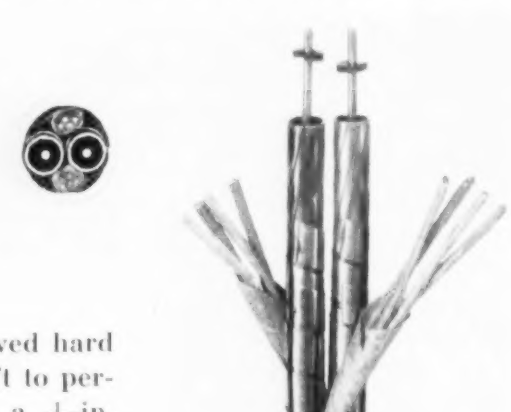
It will be impossible to even outline the electrical theory underlying the cable and its associated equipment. It consists of two co-axial units and two quads of 19-gage wire, stranded together, wrapped with two thicknesses of paper, and then sheathed with lead. A cross-section is shown in the accompanying view. Each co-axial unit is made up of an outer copper shell and a central wire on which slotted rubber disks have been snapped at $\frac{3}{4}$-in. intervals for insulating purposes and centering the inner conductor.

In construction certain difficulties were encountered. For one it was found that dead soft copper, ordinarily used for conductors, would not do. A harder metal was required for the central conductor to give sufficient tensile strength for installation, and to allow the rubber disk insulators to be snapped on by machine. But the wire must also be soft enough to withstand a certain amount of stretching without breaking. To meet these requirements a suitable copper rod was drawn to a size approximating the desired diameter, but somewhat larger, after which it was annealed and then drawn to the correct size and hardness.

Insulation between the outer shell and the inner wire also presented difficulties. The solution was found in an improved hard rubber compound sufficiently soft to permit disks being punched from a $\frac{1}{16}$-in. sheet, and elastic enough to support the central conductor and keep it in its proper place. The outer shell for each large conductor is made of overlapping copper tapes, stranded in spirals, and reinforced by two windings of steel tape.

These steel tapes also shield the co-axial against interference from the other unit and from outside sources such as lightning, radio, and other disturbances. The size of the completed co-axial is only about $\frac{1}{3}$ in. diameter, and the lead sheathing is $\frac{7}{8}$ in. outside diameter.

Co-Axial Cable, $\frac{7}{8}$ In. Diameter, Sheathed in 0.085-In. Lead. Main conductors have rubber disks centering them inside segmental copper tube, itself wrapped with steel tape. Two 4-strand cables complete the assembly. Courtesy Bell Telephone Laboratories



The co-axial transmission line recently installed at radio broadcasting station WTAM in Cleveland, as described by William S. Duttera in the March 1939 issue of *Electronics*, consists of an outer conductor of aluminum tubing with 3-in. inside diameter and 0.120-in. wall thickness, and an inner conductor, also of aluminum tubing, having an outer diameter of $\frac{3}{4}$ in. with a wall thickness of 0.065 in.

Overhead Power Transmission

With the steady increase in distances to which electrical power is delivered has come an equally steady increase in the voltage and amperage of the transmitted current. Losses en-route can be reduced by making the conductors bigger — that is, of larger cross section and of larger surface area. Single wire conductors are suitable for perhaps 40,000-volt transmissions; stranded cable are more economical for higher voltages. To minimize weight (and therefore cost of supporting towers) steel centered aluminum cables became quite popular.

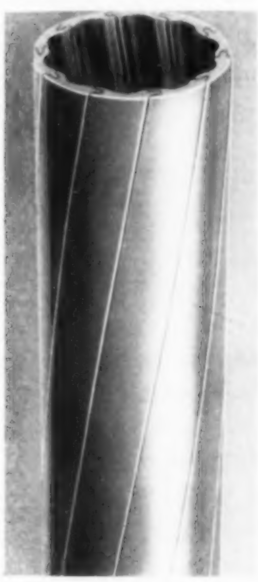
As the voltages reached and passed 150,000, the so-called corona losses became important. This is a direct leakage from conductor to the surrounding atmosphere, and can be kept at a low figure only by making the conductor of relatively large diameter. But a heavy cable was not desirable. A cable of large circumference which at the same time is light in weight is the hollow cable. Its advantages are an increased current carrying capacity, a better dissipation of heat, a reduction of resistance to alternating current, and less corona loss.

Two principal

types of hollow copper cable are now in use: *(a)* Flexible hard drawn copper tubular conductor composed of segments (a European design but adapted to American needs), the edges of which interengage in a tongue-and-groove assembly, and having no internal supporting member, and *(b)* the twisted I-beam core of copper, around the circumference of which strands of copper wire are laid in the usual manner.

Stranded Cable With Twisted Bar for Core, Adaptable for High Voltages or Frequencies. Made by Anaconda Wire and Cable Co.

In the manufacture of the first named, segments are drawn in the usual manner with the exception that special dies are used which form a lip or tongue on one side of the segment and a corresponding groove on the other. The segments are drawn from copper rods, butt welded together automatically to form a continuous piece one mile long. The cable is then formed by drawing the tongue-and-groove segments through a forming die or head so designed that it closes the adjacent tongues and grooves to interlock together in a spiral form.



Hollow Copper Conductor for Large Power Transmissions, Designed to Reduce the Corona Losses of High Voltage. 1.40-in. outside diameter, made of 10 interlocking segments, 0.080-in. minimum thickness; area is 512,000 circular mils. (Courtesy General Cable Corp.)

Connectors for joining two pieces of this hollow cable consist of central plugs to prevent its collapse under the action of wedge-shaped sleeves, forced together by right-and-left hand threads on an outer casing. Elements of this joint perform functions similar to those of a pipe union.

An interesting installation of this type of cable is that at the Boulder Dam project, where it has the responsibility of carrying power 271 miles to Los Angeles. This conductor is 1.4 in. diameter and is composed of ten interlocking segments. It weighs only 1.57 lb. per ft., which means that lighter towers and general construction could be employed than would have been necessary with heavier cable. Copper cable of the conventional concentric strand type, of similar overall diameter, would have weighed 1.63 lb. per ft.; an aluminum cable, steel reinforced, of same overall size, containing 66 aluminum wires and 19 steel wires, weighed 1.85 lb. per ft.

The stranded cable with twisted I-beam core likewise requires specially designed machinery for its manufacture. It is used with great efficiency where transmission at high voltage is undertaken, where heavy current must be carried, or where high frequency is used, as at commercial radio stations and at electric furnaces.

Underground Power

One of the great problems in connection with high voltage and high tension underground cable is that of insulation. When it is desired to design a cable to carry higher voltage than has heretofore been the practice, one of three methods is resorted to—*(a)* the brute force method, *(b)* the improved quality method and *(c)* a combination of the two. The first is to add to the insulation thickness until sufficient has been added to carry the required voltage. Thus, the Commonwealth Edison Co.'s standards call for 4/64-in. insulation of impregnated paper for voltages in the hundreds, $\frac{5}{64}$ in. for multiconductors of about 4400 volts, and $\frac{9}{64}$ in. for three-phase, 12,000-volt lines. Evidently this trend has its limitations. When the voltage becomes high, a proportional increase in thickness of insulation may not be sufficient to take care of the extra voltage, and additional insulation out of all proportion to the voltage increase may be required. This considerably increases the dielectric loss and the cost as well.

In such cases method (b) is resorted to. Herman Halperin outlined modern developments in a paper for the 1939 Midwest Power

Conference in Chicago. Most attention in the 1920's was focused on impregnated paper insulation; lately rubber and varnished cambric has been under scrutiny. Solid type of impregnated, paper-insulated cable has proved successful for three-phase circuits at 66,000 volts. Above this the oil-filled cable is more economical, as will be described presently.

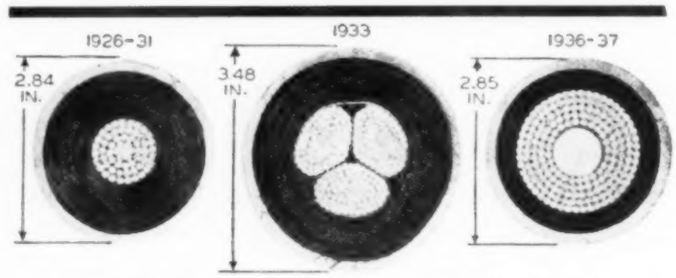
Mr. Halperin notes that electrical stresses existing in the insulation between adjacent conductors in a cable cause its deterioration, even at moderately high voltage. For that reason, shielded cable is usually specified for 15,000 volts and higher. In this cable, a thin nonmagnetic metallic tape, such as tinned copper or, more recently, "K" monel, is wrapped outside the insulation on each conductor. Single conductors of this sort are usually wrapped with inpregnated tape, to protect them from mechanical damage during handling and laying. If two or three are assembled, no belt insulation is applied.

The solid or conventional type of cable has this principal defect — that when insulated with oil-impregnated paper, voids are likely to form which, containing traces of air and other gases under low absolute pressures (high vacuum), will tend to break down electrically under a relatively small stress, causing loss of current and rapid deterioration of the insulation.

With oil-filled cable, the voids are more easily detected and may be filled as rapidly as they are formed, in which case there will be no voids nor ionization to cause loss of current. Or, the voids may be filled (in the gas-filled cable) with gas under a pressure which is consistently maintained well above atmospheric, and this improves their dielectric strength. Both of these methods permit a higher electrical stress on the insulation, or permit the use of a thinner insulation for a given voltage. This results in a material saving even though it involves an additional cost of accessories.

Oil-filled cables are the result of about 40 years of effort to obtain more economical designs for underground systems, but it is only during the past 10 or 12 years that any pronounced progress has been made. Oil-filled cables have definite longitudinal channels through which oil may flow. Since power cable is usually subjected to changes in temperature in service, due to changing daily load cycles in addition to seasonal cycles, expansible oil reservoirs are connected to such cable at intervals so that pressure may be maintained and volumetric changes taken care of. Though pressure is maintained, no attempt is made to insure positive circulation; oil is not pumped through the cable, other than that certain amount of natural circulation resulting from temperature changes. The system must insure that there shall never be any time when voids can form in the insulation, and that there shall always be a supply of oil at hand to fill incipient voids as quickly as they form.

There are three main types of oil-filled cables — *(a)* the single-conductor type has a stranded conductor around a hollow core at the center of the cable cross section, allowing a relatively large feed channel with correspondingly low longitudinal flow resistance, *(b)* the three-conductor type cable has flexible oil channels inserted in the filler spaces, allowing seepage of oil through the outer walls and *(c)* the channel type, single-conductor cable, which has a stranded conductor but not a core, the oil channels being formed directly within the lead sheath.



Cross Sections of Three Types of Oil-Filled Cable: Single Conductor (1926), Three Conductor (1933), Stranded Conductor Without Core (1936)

Complications arising with oil-filled cables are principally questions of faulty installations or faulty engineering. Knowledge of certain principles, and special equipment for installation and maintenance are required. Oil- or compound-impregnated paper so far has been found the most satisfactory insulation. Compound and paper of the right properties and quality are requisites for a high-voltage cable of high initial dielectric strength. "Today," to quote G. B. Shanklin of the General Electric Co., "the average working voltage stress in oil-filled cable is from 80 to 143 volts per mil, depending upon voltage rating. This is more than twice that of the solid type."

Successful oil-filled cable practice depends on the use of a stable non-freezing oil of supe-

rior electrical properties; the right quality of wood pulp paper, compactly and uniformly applied and of predetermined density; the removal and rigid subsequent exclusion of all impurities, such as moisture and gas (both free and in solution) from the cable during manufacture and from all accessories and fittings during installation; maintenance of positive pressure inside the entire length of cable and other parts of the oil system at all times; and care that this oil pressure does not exceed safe working limits, as determined by the mechanical strength of cable sheath and accessories.

From recent experience with the oil-filled cable it has been found that benefits are to be derived from maintaining positive pressure during shipment, installation and service. To maintain pressure requires a pressure medium. Two such mediums, recognized as being suitable, are oil and gas. The possibility of using *gas* as such a medium is interesting to research workers and promises a more versatile field because of its simplicity. It is believed that gas-filled cable would solve a real problem for use as risers in tall buildings and in localities where steep hills are encountered. Good electrical and non-toxic properties are required; nitrogen has been used and certain of the modern refrigerants have promise.

Gas-filled cables have been of especial interest to European engineers. In this country the pressures and voltages are rather low — 10 to 15 psi., and 40,000 volts respectively, the idea being to have a slight positive pressure at all times, thereby cutting down the ionization at incipient voids. European practice runs to much higher pressure, say nitrogen at 200 psi., wherein a cable of solid type is installed in a steel pipe capable of withstanding this pressure. The theory is that voids in the insulation are squeezed shut by the excessive outside pressure.

No one associated with the cable industry but knows that finality has not been reached. Physical, chemical, and electrical requirements of dielectric materials are very exacting. The application of scientific and engineering effort towards further improvements in metals and equipment for the manufacture of cable apparently is justified by the results thus far obtained. New raw materials and alloys, together with new designs of cable, will be forthcoming from time to time, and new electrical devices will be invented which will require still further improved types of conductors.

Magnesium Castings Used in Germany

Owing to the shortage of most commercial metals in Germany during the last ten years (lack of self sufficiency and existence of trade barriers) great efforts have been made to utilize magnesium and its alloys, for which Germany has ample raw materials. This situation is reflected by many papers in the technical press, which in turn are summarized in *The Metallurgist* (Supplement to *The Engineer*) for February and April 1939 and *The Metal Industry* for May 26, 1939.

According to these summaries the casting alloys have been used to a much greater extent than the forged or rolled ones. Casting alloys include those made in sand molds, die castings and pressure die castings. Their mechanical properties compare favorably with aluminum casting alloys when the specific gravity is taken into account. Applications include extensive uses where motion is required or where inertia effects are to be taken into account. The aircraft, automotive and railroad industries are large users. Likewise manufacturers of hand tools. In heavier stationary machines the uses are confined to low-stressed parts, like eccentrics and valve motions, gear cases, oil pans, and housings of all sorts.

Most reliance is placed on the three families of alloys, with aluminum, silicon and manganese, respectively, used for the most part without heat treatment. In the numbering system the symbols are preceded by the letter G representing *Guss* or casting, and the subscripts indicate roughly the approximate percentages. The above alloys may be noted thus:

The aluminum series: G $Mg\text{-}Al_{10}\text{-}Zn_{0.5}$; G $Mg\text{-}Al_6\text{-}Zn_3$; G $Mg\text{-}Al_4\text{-}Zn_3$; G $Mg\text{-}Al_3\text{-}Zn_1$; all containing up to 0.5% manganese. The first mentioned corresponds roughly to Dowmetal R, the common American die casting alloy, and the second is Dowmetal H, recommended for salt water resistance.

Silicon alloy: G $Mg\text{-}Si_2$ for liquid tight castings. *(Continued on page 78)*

Correspondence and Foreign Letters

Standard Sample of Leaded Steel

WASHINGTON

To the Editor of METAL PROGRESS:

In view of the discussion of leaded steel and its manufacture that has been carried on in the columns of METAL PROGRESS, your readers will be interested to know that a standard sample for analytical purposes, known as No. 130, has been prepared by the National Bureau of Standards. It is available at a price of $2 per bottle of 150 g. and is issued with the following certificate of analysis: Carbon 0.454%, manganese 0.687%, phosphorus 0.021%, silicon 0.239% and lead 0.203%.

Two other steel samples of interest have also been recently added to the list of standard samples: Nickel steel, No. 126, is as follows: Nickel 36.41%, carbon 0.035%, manganese 0.504%, silicon 0.109%, copper 0.098% and cobalt 0.008%. The high sulphur steel, No. 129, has the following composition: Carbon 0.131%, manganese 0.855%, phosphorus 0.109%, sulphur 0.260%, silicon 0.014% and copper 0.166%.

LYMAN J. BRIGGS
Director, National Bureau of Standards

The "Brittle Constituent" in Chromium-Nickel-Iron Alloys

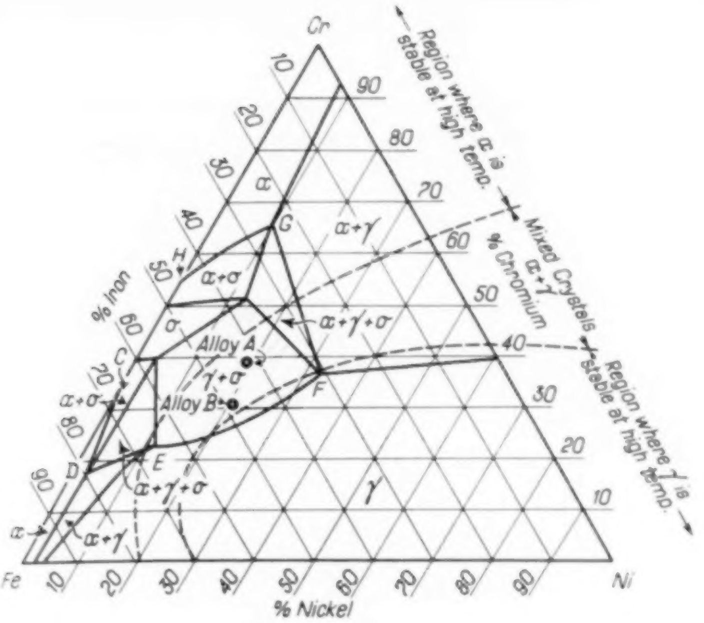
KREFELD, GERMANY

To the Editor of METAL PROGRESS:

It has been known for some time that a new structural constituent occurs in chromium-iron alloys of certain analyses that is hard, brittle and non-magnetic and has therefore been designated the "brittle" or "B constituent". It was later determined that this constituent corresponds to the compound FeCr, and its occurrence was also confirmed in the ternary chromium-nickel-iron alloys which are not purely austenitic after quenching from a high temperature but contain more or less alpha iron or ferrite (alpha or delta phase). On long annealing at temperatures between 600 and 950° C. (1100 and 1650° F.) some of the ferrite is converted into the compound FeCr and the gamma solid solution, austenite. This action is accompanied by a pronounced decrease in volume, and an embrittlement or decrease in toughness.

The latter phenomenon can also be observed in those heat resisting steels (Ni-Cr-Fe alloys) whose structural constitution consists of austenite and ferrite and which have been heated for a long time in the above-mentioned temperature range. It occurs likewise in a group of acid resisting steels containing 18% Cr and 8% Ni which, as the result of further additions of ferrite-forming elements such as silicon, molybdenum or the carbide-forming elements titanium and columbium, contain more or less ferrite.

First let us outline the conditions under which the brittle constituent forms. (In what follows this "B constituent" shall be designated as the sigma phase.) Investigation by Messrs. SCHAFMEISTER and ERGANG led to the construction of a ternary diagram, which is reproduced herewith showing conditions that are in equilibrium during annealing at 800° C. (1475° F.). While the sigma phase does not occur in any



Ternary Diagram Showing in Dotted Lines the Approximate Equilibrium Constitution at High Temperatures (1200° C. or 2200° F.) and the Regions as Mapped in Solid Lines by Schafmeister and Ergang Where Sigma Phase Will Occur After Long Annealing at 800° C. (1475° F.)

obtained. In other words, the structure stable at very high temperatures consists of ferrite with or without austenite, and the brittleness due to the FeCr compound is eliminated.

The second curve sheet shows how the hardness is affected by formation of the sigma phase with rising tempering temperature between 850 and 1050° C. (1550 to 1925° F.). Alloy *A*, with 39% Cr and 18.8% Ni, in accordance with its position in the alpha plus gamma field at high temperatures contains about 40% of magnetic ferrite in the quenched condition, in addition to the 60% of non-magnetic austenite. By annealing at 800° for 200 hr. the original magnetic alloy becomes non-magnetic through the complete change of this ferrite to FeCr and austenite; it also acquires a hardness of 425 Brinell. On tempering at 1000° C. (1835° F.) for the short period of 30 min., hardness drops back to its original value and simultaneously the alloy again becomes magnetic, which indicates that the non-magnetic sigma phase (FeCr) is brought back into alpha solid solution; thereby the embrittlement is cured.

In contrast, Alloy *B* with 30.2% Cr and 20.7% Ni lies near the gamma field at high temperatures and consequently after quenching contains only about *(Continued on page 98)*

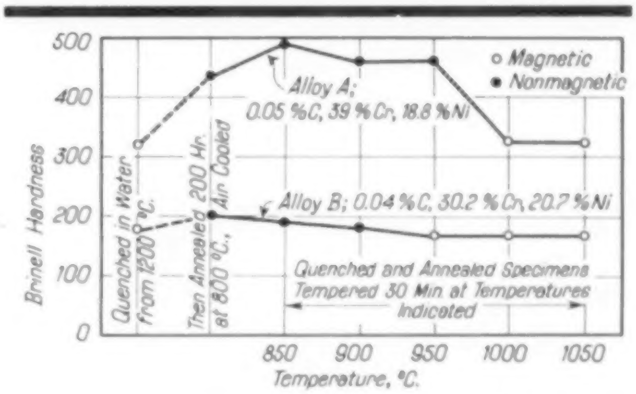
Tensile Properties of 18-8 (With Mo and Cb) After Annealing at 750° C. (1380° F.)

Heat Treatment	Yield Point	Ultimate Strength	Elongation	Reduction of Area	Impact Strength★
Quenched in water from 1050° C. (1925° F.)	59,300	96,500	48.0	68.6	17.9
Annealed 1 hr. at 750° C. (1380° F.)	56,000	98,200	46.0	64.0	16.6
Annealed 10 hr.	60,500	102,000	37.2	53.8	14.9
Annealed 50 hr.	62,500	104,000	35.4	39.0	12.2

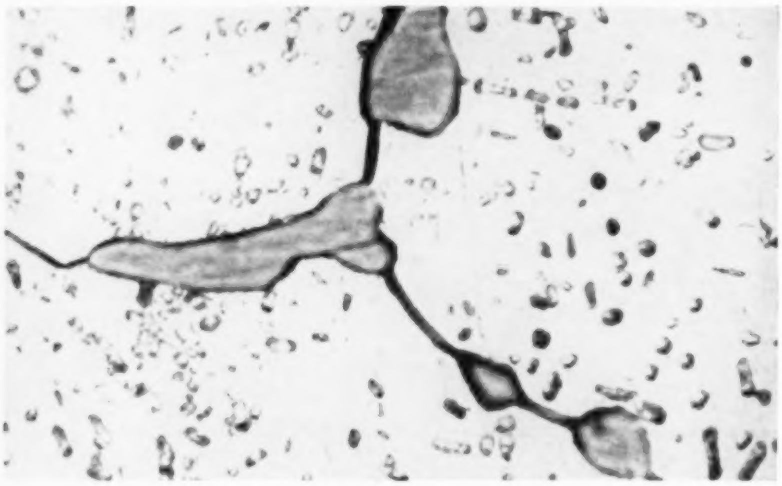
★In m.-kg. per sq.cm., Charpy test piece 10 mm. square notched 3 mm. deep.

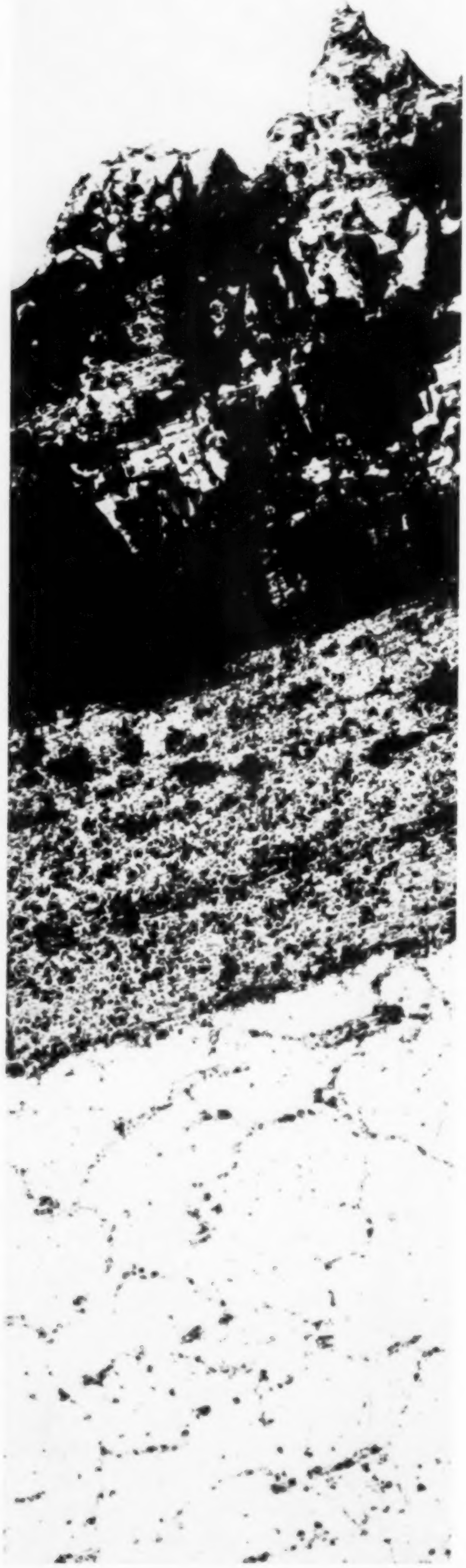
of the alloys quenched from a temperature above 1000° C. (1850° F.) — for instance, 1200° C. — it does form after long annealing, say 200 hr., at 800° C. Approximate conditions that exist above 1000° C. are shown by the two dotted curves on the diagram. Further information on the changes in amount of sigma with changing temperature is to be had in a letter from John S. Marsh in Metal Progress for March, 1939.

The field where sigma phase can exist extends in a roughly rectangular area from the binary chromium-iron system and may be expected in alloys ranging from 20% Cr, 80% Fe to about 60% Cr, 20% Fe. Generally speaking, increase in nickel contracts this range; above about 33% nickel, no sigma phase will form during an anneal at 800° C. If an alloy whose composition lies within the area marked by *C-D-E-F-G-H* (and which has been annealed say 200 hr. at 800° C.) is reheated to a temperature above 1000° C., then the precipitated sigma phase will be redissolved and after correspondingly rapid cooling, the alpha phase or the mixed alpha and delta phases will again be



Alloy A Is Hardened by Precipitation of Considerable Amounts of Sigma Phase (FeCr Compound) During Heatings in the Range of 800 to 950° C. (1475 to 1750° F.)





Intergranular Sulphides in a Cupro-Nickel. 500×; slightly etched with acid ferric chloride. At left: Sulphide scale and intergranular segregates in wrought iron. 200×; unetched

More Sulphide Contaminations

PHILADELPHIA, PA.

To the Editor of METAL PROGRESS:

G. K. MANNING's article "Sulphide Inclusions from Clay Packing" in December's METAL PROGRESS again reminds one of the ubiquity of the element sulphur, and of its potential corrosiveness when present in forms and amounts which would appear quite innocuous. Two photomicrographs, herewith submitted, supplement Mr. MANNING's observations.

The top engraving shows intergranular inclusions of nickel sulphide in a cupro-nickel which had been heated for some hours at 1350° F. in a reducing atmosphere in which small amounts of sulphur gases (0.5% or less) were inadvertently present. The photograph at left is the corroded structure of the cross section, near the outside, of the ⅛-in. wall of a wrought iron thermocouple protection tube which had been part of the interior of a retort used for re-activating bone char; this char, used as a filtering medium in the clarification of sugar solutions, had apparently become contaminated with organic sulphur compounds. The retort temperature was 1200° F.

The corroded tube had little strength and it had scaled badly on the outside. The microstructure shows two layers of scale — an outer, thick, brittle, and fairly adherent layer; and an inner, somewhat thinner, and more compact layer which clung tightly to the metal surface. The total thickness of the dual scale was about 0.025 in. The metal, from wall to wall, had all boundaries filled with a sulphide, and this sulphide was the principal constituent of the scale also. Analysis of the wall metal (freed from scale) gave 0.451% sulphur.

L. R. VANWERT
Research Department, Leeds & Northrup Co.

Variations in European Specifications for Iron Castings

TURIN, ITALY

To the Editor of METAL PROGRESS:

While international standardization of testing methods for structural steels seems to be on its way, the same optimistic statement can hardly be made after comparing the testing methods for iron castings now in use in different European countries. Such a comparison shows numerous and essential differences, not only in the details of execution, but also in the general principles underlying the selection of test pieces and testing methods, and the interpretation of results.

Frequently these differences are a consequence of different traditional manufacturing methods — or of diverse interpretations of experimental results obtained under non-uniform conditions. In these cases it is evident that further discussion and comparison of actual results, as well as experimental researches, may be necessary to reach an acceptable and uniform practice. But in many other cases the reasons for the above-mentioned discrepancies seem very hard to find. In such instances, an efficient process of complete standardization would appear to be a simple matter of conference, discussion and good will, and should not meet with real difficulties.

An analysis of these different cases would obviously take too long, but a few examples may be sufficient to illustrate the meaning of the above statements.

An example of discrepancies belonging to the first group is supplied by the different methods taken in different countries to insure that the test piece has the same mechanical properties as the casting itself. Sometimes (as in French specifications) the test pieces must always be taken from lugs directly connected with the casting; test pieces cast separately are only allowed when the form and dimensions of castings make it practically impossible to cast attached test pieces. In other countries test pieces are always cast separately under strictly fixed conditions; this is true of Italian specifications. Finally other specifications (as the German and British) admit both methods, as may be agreed upon.

Another example of the same class is the problem of small sized test pieces. Experiments attempting to establish well-defined relations between the properties of full sized and of small scale test pieces, have resulted in data of such large dispersion that further extensive researches are obviously necessary before general conclusions may be arrived at. Yet the great practical importance of this problem is well known, especially in all experiments prior to the determination of the causes of failures of castings.

The second group mentioned above includes a great number of points concerning, generally, questions of details rather than basic principles. A general agreement would appear to be extremely easy, for sometimes it would be even difficult to discover the reasons why the existing discrepancies have not yet been removed. Yet the elimination of some of these discrepancies — even though concerning unimportant details — would often facilitate the comparison of experimental results and thus, indirectly, make great progress towards general European standardization.

A few examples out of a long list may be quoted:

Why are so many different sizes still permissible in different countries for bend tests? (It must be remarked that the differences are often too small to be justified by any supposed convenience or possibility of cutting the test pieces from the original casting.) For instance, German, Italian and Swiss specifications fix a single cylindrical test piece of 30-mm. diameter, and 600 mm. between points of support. British specifications include three different sizes according to thickness of casting (which may well be justified), but the distance between points of support for the usual test piece of 30-mm. diameter, is only 457 mm. (18 in.). Dutch specifications also include three sizes of test pieces, but the diameter of the smallest is 20 mm. (instead of the 22.23 mm. or ⅞ in. of the British test piece) and the largest has a diameter of 40 mm. instead of 55.88 mm. for the largest British test piece. Deformation in bending is usually measured only by the deflection at the time of fracture, but some specifications (such as the British, French and Swiss) require the engineer to determine the deflection under a series of loads.

A complete review of the many more instances of discrepancy in the same classes as the few mentioned would confirm the pessimistic statement expressed at the outset.

FEDERICO GIOLITTI
Consulting Metallurgist

Slag Prints

LEOBEN, GERMANY

To the Editor of METAL PROGRESS:

In the March 1936 issue of METAL PROGRESS I suggested a method, originated by M. NIESSNER which I called "iron oxide printing". In short, this is done as follows:

Gelatine paper is moistened with a dilute aqueous solution of hydrochloric acid (5 ml. conc. HCl to 100 ml. H_2O) and then lightly pressed between pieces of filter paper to remove all drops of liquid. The moistened paper is then pressed with its gelatinized side against the polished surface of the iron or steel specimen for a time ranging from a few seconds up to one or two minutes, depending on the nature of the inclusions, and best found by a preliminary trial. The paper is then removed and put into a solution of potassium ferrocyanide (20 g. $K_4(FeCN)_6$ to 1000 ml. H_2O), which acts as a developer in such a way that wherever iron-bearing inclusions are in the specimen of iron or steel, dark blue spots appear on the print, which thus gives a picture of the size and distribution of the inclusions.

This method has been improved by H. DIENBAUER, who found that in most cases (but not in all) the sharpness of the prints is improved by adding 15 g. of common salt (NaCl) to the above-mentioned dilute hydrochloric acid.

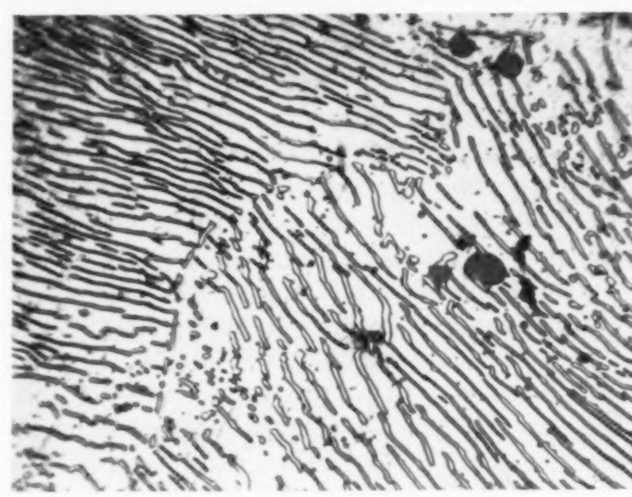
Another improvement is the use of ordinary photographic paper instead of gelatine paper. By using photographic paper in connection with the two above-mentioned solutions of hydrochloric acid and potassium ferrocyanide, sulphide inclusions also appear with the same accuracy as the iron-bearing inclusions. Therefore I should now like to call the method "slag printing" because it reveals both oxide and sulphide inclusions with only one print.

When using these methods, either "iron oxide printing" or "slag printing", attention should be given to the following points:

The surface of the polished specimen must be clean and no scratches should be present. If scratches contain finely powdered iron-bearing dust from the grinding or polishing operation, they appear on the print as dark blue lines. However, it is really not difficult to distinguish these "scratch-prints" from veritable inclusions. Cleanliness in working is a prime factor. The air in the room where the prints are made must also be free from iron-bearing dust; otherwise the print will contain dark blue rounded points *outside* the area covered by the specimen.

Finally, I should point out the fact that in certain cases differences in the structure of the metal itself are also revealed by the above-described printing methods. If, for instance, mottled cast iron is printed, the mottles where the carbon is present in the form of graphite are printed as dark blue points. It might be supposed that this circumstance would diminish the utility of the methods, but this is not the case whenever the specimen that is printed is also examined microscopically. When this is done (and it can be supposed it will be whenever slags are looked for), then it will not be difficult to distinguish on the print slag inclusions from mere differences in the structure of the metal itself.

ROLAND MITSCHE
Professor, Montanistische Hochschule



Pearlite in White Heart Malleable, Etched in 2% Nital, Magnified 600 Diameters. Note that, for the most part, the carbide plates have the same color tone as the ferrite laminations

Etching of Cementite in Pearlite

BIRMINGHAM, ENGLAND

To the Editor of METAL PROGRESS:

We have followed, on this side, with much interest the discussions in METAL PROGRESS and *Transactions* centering on the accepted or traditional definitions and descriptions of pearlite.

To quote from Sauveur's "Metallography" (1926 Edition) page 50: "The carbide plates remain bright, not being affected by the usual etching reagents, while the ferrite plates appear dark because of their being somewhat tarnished

by the etching, and also because, being depressed owing to their greater softness, they stand in the shadow of the carbide plates."

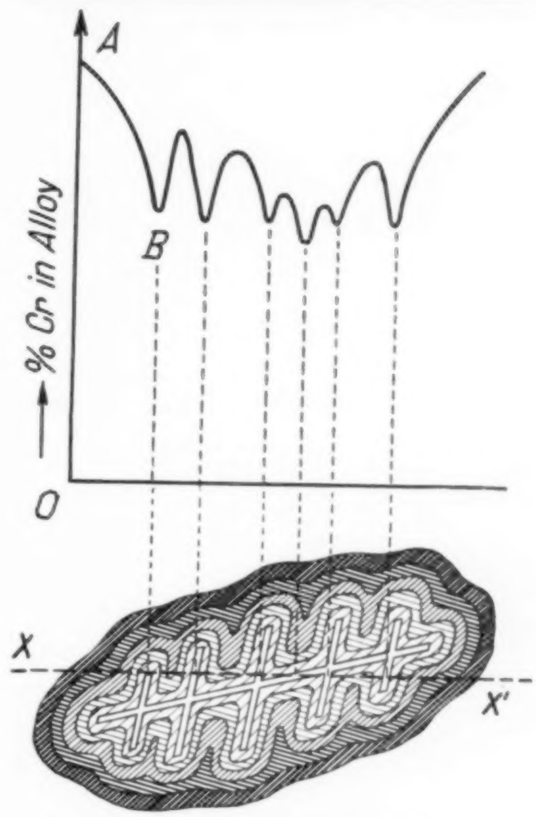
Recently in examining some coarse pearlite in white heart malleable iron, I observed the structure shown on the opposite page. It indicates that the ferrite in pearlite remains bright, but that either the extreme edges of the cementite plate, or the immediate ferritic surroundings thereof, are attacked in etching. It is likely when plates appear entirely dark that that region has been too deeply etched. There is a possibility for the cementite plates to be removed during etching, leaving an elongated cavity appearing dark under the microscope. The finer the pearlite (and thinner the plates) the greater the likelihood of removal of the cementite plate.

The specimen of malleable iron examined was etched in 2% nital, and the magnification of the photomicrograph is 600 diameters.

F. DAVID WATERFALL

Heat Treatment Dept., The Cassel Cyanide Co., Ltd.

EDITOR'S NOTE: — J. R. VILELLA in his lectures before the 1937 ⊕ Convention, as recorded in the book "Metallographic Technique for Steel", recommends a solution of picric acid in alcohol for showing maximum detail in pearlite, rather than nitric acid in alcohol (nital) as used by Mr. WATERFALL, primarily because the former is more uniform even if slower in action. He gives two views of the same field of spheroidized cementite in which the carbide particles etched with picral are much grayer in color than when etched with nital. He says: "Picral appears to color cementite slightly, thus causing it to contrast with ferrite without the necessity of deep etching. For high magnification it is essential to avoid excessive relief of the cementite, consequently a reagent which brings about contrast by slight color difference, rather than by relief, is preferable."



Cored Structure of Primary Dendrite of Solid Solution (as of Chromium in Iron). Curve at top indicates variation in chromium content along a line such as x-x'

Chemical Heterogeneity in Alloys

PARIS, FRANCE

To the Editor of
METAL PROGRESS:

All industrial metals and alloys have two sources of unsoundness; first, physical heterogeneity, because they are formed of differently oriented anisotropic crystals; second, chemical heterogeneity, because they are composed either of various constituents, or of solid solutions whose concentration is not uniform.

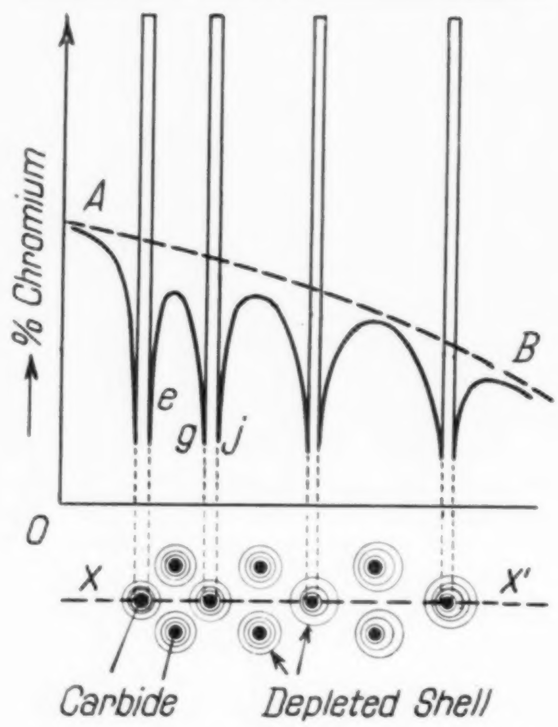
The second category, chemical heterogeneity in ingots and castings, can be considered under three different aspects corresponding to three different dimensional scales, and in all cases it can be represented by isochemical surfaces and curves by which may be defined the maximum difference in concentration, the linear extent or distance between concentration points, and the concentration gradient (see a former letter to METAL PROGRESS, February 1935, p. 42).

1. The first degree of heterogeneity is based on the dimensional scale of the ingot and constitutes the major or "global" segregation. It can be exposed to view by macrographical etching showing the topography or, more exactly, the form of the isochemical curves, which may be plotted by direct experimentation and measurement by chemical or microchemical analysis or any other physico-chemical method. The maximum difference in concentration and the concentration gradient both vary over wide limits; it is the desire of the metallurgist to minimize them.

2. The second degree of heterogeneity is based on the scale of the solidification structure or macrostructure. It shows itself in the unequal concentration of elements in the dendrites of solid solution, varying from the axis to the periphery of the dendrites. It is known as "primary minor segregation" or dendritic segregation. It results from the gradual solidi-

fication of solid solutions which by their nature have different compositions at different temperatures; this "cored" structure is the cause of diffusion to the interior of the crystallizing solid phase. Such diffusion depends on temperature and time of solidification, on concentration differences in the course of solidification, and, consequently, on the difference between the temperature where solidification begins and where it ends, as well as on the size of the macrostructure, which depends on the cooling rate during solidification. Chemical attack reveals the macrostructure of an alloy simply because of the dendritic character of this segregation. These variations in concentration are graphically shown in the first figure, at the head of this communication.

3. On a still smaller scale is the third degree of heterogeneity. This "secondary" minor segregation (or transformation segregation) is on a microstructural scale and is the result of transformation in the solid state, just as the second degree of heterogeneity comes about during solidification. For instance, precipitation of one constituent within a solid solution is, as we have already explained in Metal Progress for September 1936, preceded and accompanied by a heterogeneity caused by the rapidly varying concentration of the solid solution at the point of contact with the precipitating constituent. The particles of this phase are also often surrounded with material of high concentration gradient, because the rate of the diffusion is lower than at solidification temperatures. This is graphically shown in the second figure above, representing the precipitation of chromium-rich cementite in a stainless steel. Chemical attack reveals it as before, but it can only be observed under the microscope.



Cored Structures Surrounding Complex Carbides Precipitated From Solid Solutions (as of Stainless Steel). Curve A-B represents regional changes due to primary minor segregation, whereas solid lines indicate chromium contents from point to point, along line x-x'

No quantitative physical method exists for estimating primary minor segregation (and, of course, secondary minor segregation) that can be applied to samples small enough to be apparently homogeneous. Etching reveals only the form and extent of the zones of segregation. Rather large-sized and consequently heterogeneous samples must be used in testing to show the concentration difference in volumetric amplitude and extent (see Metal Progress for February 1935). Such micro-chemical testing is very rare; one usually deduces the extent of segregation by its effect on transformation points, on thermomagnetic or dilatometric changes, or on electrical conductivity. More rarely mechanical methods may be used as outlined in Metal Progress, July 1935.

By these methods it may be ascertained that the effects of these two kinds of minor heterogeneity may overlap with variable intensities and to variable extent. In dendritic segregation the extent will be greater, and thus cause it to be observed in the macrostructure, but the amplitude of the concentration gradient is less, owing to the more rapid diffusion at high temperatures. Secondary minor segregation, having a large amplitude (maximum difference in concentration) overlies the dendritic segregation and is often confused with it in cast products.

This congenital heterogeneity acts on the specific and global properties in varying degrees; its effect may be lessened or modified by annealing but in a very non-uniform manner. It is possible to eliminate the effect of secondary minor heterogeneity almost entirely by annealing; the effect of the primary heterogeneity may be decreased by prolonged annealing, but it is impossible to modify the major heterogeneity by annealing because of its extent.

Albert Portevin
Editor, *La Revue de Métallurgie*

SOLVING THE HARD ONES

Many a design problem that used to be troublesome is being worked out these days by the use of modern materials. Take logging trailer brake drums, for example.

Holding back 50 ton loads on long, steep grades and running high temperatures is all in their day's work. But, by making his drums of Chromium-Molybdenum (0.35-0.45% Cr.; 0.35-0.45% Mo.) iron, one of the leading manufacturers has more than met the severe operating conditions.

The iron is strong and tough, with good resistance to abrasion. Furthermore, it retains these qualities after repeated heating to around 900 degrees F. followed by rapid cooling. In addition the Molybdenum content reduces the tendency to distortion due to heating — thus reducing the pounding action that leads to premature failure.

Perhaps a re-check of your own materials specifications is in order. Our technical booklet, "Molybdenum in Iron" will prove helpful. It is free on request to production executives and engineers.

PRODUCERS OF MOLYBDENUM BRIQUETTES, FERRO-MOLYBDENUM, AND CALCIUM MOLYBDATE

MOLY

Climax Mo-lyb-den-um Company
500 Fifth Avenue · New York City

Personals

Promoted by Leeds and Northrup Co., Philadelphia: LELAND R. VANWERT, to chief of the metallurgical division.

Retired: GEORGE WARDROPE SCOTT, foreman of the tool room of Northern Electric Co., Montreal, after 44 years' service.

WILLIAM A. MUDGE, formerly superintendent of research at the Huntington, W. Va., rolling mill of International Nickel Co., has now been added to the technical service division of the New York office.

ORVILLE C. HOOVER, formerly metallurgist of the Oberhelman and Ritter Foundry Co., Cincinnati, Ohio, is now foundry superintendent of The Acme Foundry Co. of Detroit.

Appointed director of chemical research for Rustless Iron and Steel Corp., Baltimore: ALEXANDER L. FEILD, who will also remain in charge of patent activities and continue as consulting metallurgist for Rustless.

E. P. GEARY, until recently assistant managing director of British Stainless Steel, Ltd., England, has been appointed assistant vice-president in charge of sales for Rustless Iron and Steel Corp.

Elected vice-president and general manager of sales of Columbia Steel Co.: J. R. GREGORY, formerly assistant general manager of sales. F. B. DELONG has been made vice-president in charge of sales, Los Angeles district; C. S. CONRAD, assistant general manager of sales, manufacturing and construction accounts; and HARRY E. ROGERS, San Francisco sales manager.

H. W. GRAHAM, director of metallurgy and research, Jones & Laughlin Steel Corp., Pittsburgh, and H. K. WORK, manager of research and development, were among the speakers at the winter meeting of the Industrial Research Institute last month. Mr. Graham is chairman of the executive committee.

JOSEPH WINLOCK, chief metallurgist, Edward G. Budd Mfg. Co., Philadelphia, has been selected as the first "Sauveur Night" lecturer for the Boston Chapter meeting on Jan. 5.

STANLEY J. KLEIN, formerly with Farrel-Birmingham Mfg. Co., Buffalo, is now heat treater in the Electromatic Typewriter Division, International Business Machines Co., Rochester, N. Y.

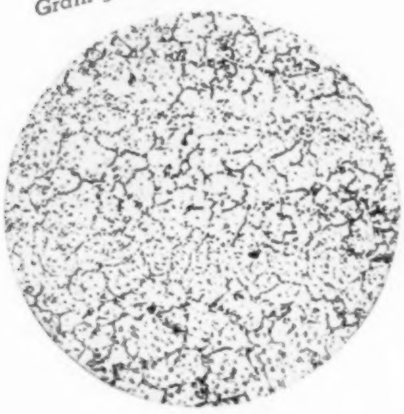
E. R. S. REEDER has been appointed district sales manager for the new warehouse and sales office of William Jessop & Sons, Inc., in Detroit.

C. S. WILSON is now practicing as a consulting engineer in Driggs, Idaho.

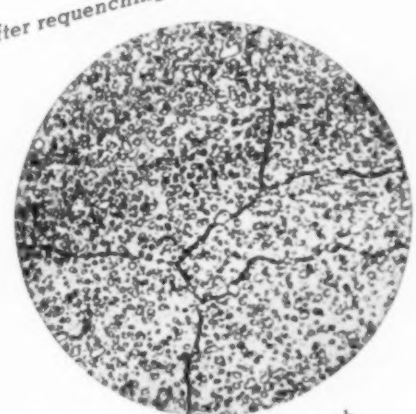
How to Re-quench High-speed Steel

without excessive grain growth

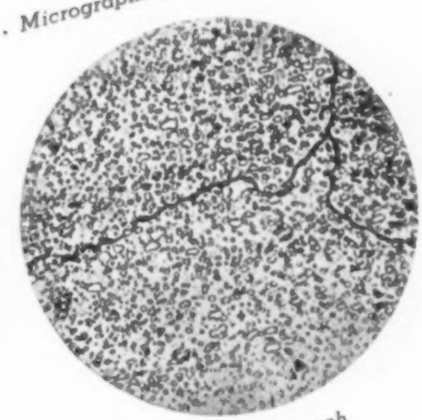
Grain growth of high speed tool steels after requenching without proper precautions · Micrographs at 300 magnifications



First quench



Second successive quench



Third successive quench

When previously-hardened high-speed steel is heated for re-quenching, special precautions must be taken to avoid excessive grain growth.

Annealing at 1625 to 1675 deg. F., is frequently recommended. Annealing, however, is not enough to prevent grain growth unless the stresses of the previous hardening are removed by very slow heating before reaching 1350 to 1450 deg. F., the temperature range at which grain growth occurs.

The following procedure is recommended as the best method of preventing excessive grain growth:

Heat to 1100 deg. F., very slowly, from 1100 to 1350 deg. F., at a normal rate, and at a rate not exceeding 50 deg. per hour between 1350 and 1450 deg. F. Soak. Heat to 1650 deg. F and soak. Transfer to high temperature furnace and heat normally for quenching. When salvaging a hardened high-speed steel tool by re-forging, annealing is recommended both before and after forging.

Bethlehem makes a grade of tool steel to handle every type of metal-working job. Ask a Bethlehem tool steel specialist to help you select the exact steel to fit your job. There's no obligation, and his suggestions may save you both time and money.

BETHLEHEM STEEL COMPANY

Fast Trains

(Continued from page 42)

The claims for stainless steel are lower weight due to higher physical properties, better welding by the automatic shot-weld process, and high resistance to corrosion. No paint protection is necessary, which reduces both first cost and maintenance. Its polished surface gives an attractive appearance and is easily cleaned. In high speed operation the sandblast effect of particles from the ballast damages paint rapidly.

Advocates of low alloy, high tensile steel claim equally low weights for lower costs. These steels have from two to four times the corrosion resistance of ordinary carbon steel. They are made to various formulas and have different trade names; it is claimed that some of them have superior welding qualities.

Inasmuch as no exactly similar cars have been built using the different types of steel or aluminum, accurate weight comparisons cannot be made. Even though full use of the superior physical properties of stainless steel or aluminum is limited by deflection requirements, it should be possible to construct a lighter car of equal strength. A general comparison indicates a weight advantage for stainless steel and aluminum of at least 5%. Construction cost should be higher, due to their high cost per pound, but competition between builders has resulted in about equal bid prices.

Extensive experiments on trucks were necessary to give riding comfort at higher speeds. Among new features installed are softer springs with greater deflections, hydraulic shock absorbers to control both lateral motion and vertical spring reactions, multiple-spring systems in triple-bolster trucks, and roll stabilizers. The use of cylindrical tread contours on wheels to reduce the nosing of trucks, and the grinding of treads to secure true rotundity and concentricity and balance, also soften the ride. Vertical vibration in the cars has been reduced by stiffening the car-body, and fore-and-aft lurching by tight-lock couplers with little "slack", and by softer-acting draft gears.

Diesel-electric locomotives are more commonly used in these new trains than steam locomotives. The advantages claimed for the diesel are high availability, rapid acceleration because of high tractive power at lower speeds, low maintenance costs, low fuel cost, lower rail stresses. The steam locomotive is less expensive, costing about

(Continued on page 76)

Fast Trains

(Starts on page 42)

$37 per horsepower instead of $87. However, it is harder on track at high speeds due to overbalance in the driving wheels. A radical change in the design of the steam locomotive is necessary to make it competitive.

The performance records of diesels show fewer failures than similar records for steam locomotives, even when the latter are operated in slower speed service. The multi-unit power plant is a helpful feature; if something goes wrong in one power plant the locomotive can still go on to its terminal and in many cases the defect can be repaired en route with little or no delay. A major breakage or defect on a steam engine means a failure.

The center of gravity is considerably lower than that of steam locomotives and this fact, together with the shorter rigid wheel base, makes it possible to operate the diesel-electric locomotive at about 15% higher speeds on curves. This is an important factor in making high speed schedules, particularly on runs through hilly country.

As to maintenance, the best available data are from one Western road and indicate that diesel-electrics can be maintained for no more cost than steam locomotives of similar power operating at slower speeds. A considerable amount of comparative data indicates that the steam locomotive oil consumption is approximately 4½ times that of the diesel-electric locomotives. The usual diesel fuel is 28-gravity furnace oil costing about 4¢ per gallon at the refinery; steam locomotives use a residuum costing about 2¢.

Present developments, at least in the West, are for high speed all-coach trains which can be operated at about 0.5¢ per passenger mile (fully loaded) rather than the luxury types which cost 1.1¢ per passenger mile. The all-coach trains have been remarkably successful in attracting passengers for long runs.

It is the coach type of train that primarily has the possibility of diverting traffic from private automobiles and buses to the railroads, and developing a large amount of new traffic among people in the low and medium income group. There is almost no limit to this type of travel by people who want low cost transportation with high speed and comfort. All of these are being provided in such trains. These new high speed trains in the West are now operating at about the maximum speed possible on the present track structure, without large expenditures in correcting alignment and eliminating grade crossings.

Magnesium Castings

(Continued from page 63) Manganese alloy: G Mg-Mn$_2$ fittings and sheet for welded tankage.

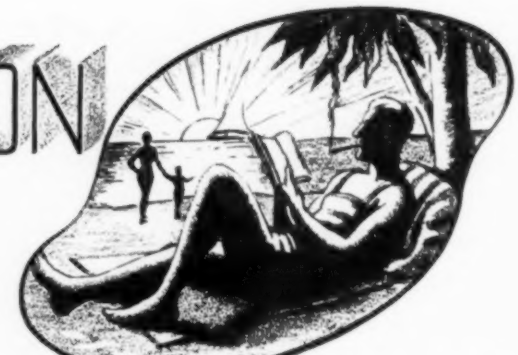
Only the 10% aluminum alloy is heat treated, in ordinary practice. This consists of an annealing or homogenizing operation alone or together with subsequent temper hardening. The homogenized condition is obtained by at least 24 hr. annealing in stages gradually reaching 750° F. in an atmosphere of SO_2, or in a bichromate bath, followed by rapid cooling. This converts a complex cast structure into rather coarse grains of a single phase. If the alloy is not heated in stages but is brought by continuous heating to the upper limit of the temperature, then the $MgAl_2$ constituent melts. The mechanical strength and appearance of the fracture are thereby impaired, since insufficient opportunity had been given for diffusion to take place during the heating. For the temper hardening treatment, the homogenized components are heated for 8 to 10 hr. at 375° F., whereupon the microstructure appears to consist of granules of eutectoid outlined with broad but irregular boundaries. Such a complete heat treatment will raise the ultimate strength of the casting (originally on the order of 25,000 psi.) to a maximum of 40,000 psi., and the hardness correspondingly.

Special melting and grain refining methods, without the use of further alloy, are said to raise the ultimate strength 1000 to 3000 psi. and the elongation 2 or 3%—rather important proportions. Exact details are not given in the publications, but consist generally in melting under a mixture of oxy-chlorides that give off oxygen. Also the melt is stirred by bubbling through it a "special gas mixture". It is said that such castings can be heat treated and come out bright, without the necessity of an SO_2 atmosphere to avoid undue oxidation and stain.

Certain magnesium alloys exhibit stress corrosion. However, the casting alloys, as well as the magnesium-manganese wrought alloys, are free from this. The high-percentage magnesium-aluminum wrought alloys are more prone to the trouble, which can, however, be mitigated by heat treatment. The trouble can also be overcome by cladding with superficial layers of magnesium-manganese sheet which is corrosion resisting.

To increase the corrosion resistance of magnesium alloys they are treated with a nitric acid alkali-bichromate pickle. Varnish is the best protection at the present time. *(Cont. on p. 82)*

PREFERRED POSITION



News from Metallurgical Headquarters

JANUARY **1940**

SILVER ANNIVERSARY

Celebrates 25 Years of Metal-Working Progress

Back in 1915 when World War I and that risky contraption, the Automobile, were imposing new demands on the metal industries, a little group of technical and practical men sat down to talk about metals—and of an organization to promote a better knowledge of them.

This year, as World War II puts these industries to another test, this organization has become the fountain-head of metallurgical knowledge—the American Society for Metals—and commemorates its silver anniversary.

These twenty-five years of activity have seen more progress in the metal industries than the preceding 200. The contribution has been the promotion of new and better metals, of improved equipment and methods for producing, processing and fabricating them. Today, is metallurgical headquarters for 12,000 men.

These years of metal progress will be discussed and reviewed in the 25th Anniversary Issue of the Society's magazine, *Metal Progress,* to be published in March.

This editorial theme will provide an ideal setting for those advertisers who, on their own part, are playing an all-important role in this progress. Write for the complete details of this March Anniversary Issue.

ADVICE

As the editor of *Metal Progress,* E. E. Thum's editorial job is easy—and difficult. Here's why:

As Editor of the monthly, Mr. Thum has a private pipeline to the greatest store of metallurgical brainpower available today — the thousands of members. As a result his editorial reservoir is always filled to overflowing with choice articles any technical editor would envy.

On the other hand, his audience is the most critical in the world. Every reader is an expert in his own right.

Another double-check on the quality of the articles that go into the magazine is the *Metal Progress* Advisory Committee. This group represents not only the technical and non-technical interests, but marketing as well is represented in the makeup of the following Advisory Committee for 1940:

Ray T. Bayless, Assistant Secretary, American Society for Metals
C. Y. Clayton, Prof. of Metallurgical Engineering, Missouri School of Mines & Metallurgy
J. J. Crowe, Mgr. Research & Development Dept., Air Reduction Co.
W. H. Eisenman, Sec'y, Amer. Soc. for Metals
Keith J. Evans, Advertising Manager, Joseph T. Ryerson & Son Co.
T. S. Fuller, Engr. of Materials, General Electric Co.
James P. Gill, Chief Metallurgist, Vanadium-Alloys Steel Co.
Oscar E. Harder, Asst. Director, Battelle Memorial Institute
Zay Jeffries, Consulting Engineer, Incandescent Lamp Dept., General Electric Co.
A. J. Phillips, Supt. of Research, American Smelting & Refining Co.
E. E. Thum, Editor of *Metal Progress*
G. T. Williams, Metallurgist, Deere & Co.

JANUARY GALLEYS

Spit and Guess

One of the monthly features of *Metal Progress* is the Editor's "Critical Points". In the January issue, Editor Thum tells of Tempills. These are small pellets that measure the surface temperature of mildly hot metals. These Tempills when laid on metal surfaces will melt at temperatures of 300° or 400°, on up to 900°, measuring the temperature within 10°. No longer will it be necessary to spit and guess, says Editor Thum.

Electrolytic Polishing

Mechanical polishing is not practical for every form of metal so metallurgy has developed polishing by electrolysis. This polishing method is described simply and briefly in the January issue — no ponderous why's and wherefore's are involved.

Miscellany

Other articles that make the first issue of 1940 sparkle include Open hearth practices . . . The story of metals used in new power and telephonic cables . . . The theory and practice of the cold working of metal . . . Report on a series of special meetings at Carnegie Institute of Technology . . . Electrical heating elements . . . and foreign correspondence. No fillers or publicity puffs.

PREFERRED POSITION

With this issue, Preferred Position makes its bow as a monthly news-service to the men who sell the metal industries.

Every advertiser desires a preferred position and *Metal Progress,* with its fine typography and flat makeup, creates a preferred position on every page.

As the monthly magazine of the American Society for Metals, it occupies a preferred position in the metallurgical field.

PREPARED BY METAL PROGRESS, THE AMERICAN SOCIETY FOR METALS' MAGAZINE
A.S.M. IS METALLURGICAL HEADQUARTERS
7016 EUCLID AVENUE **CLEVELAND, OHIO**

Magnesium Castings

(Continued from page 78) especially against electrolytic influences. A surface treatment making use of the oxide layer has also been improved very recently.

Reference has been made to the great affinity of magnesium and its alloys for oxygen, yet the danger of fire is absolutely negligible as far as the products of magnesium and its alloys (other than powder or grinding swarf) are concerned. There is some danger in the machine shop if cutting tools are not sharp, in that friction may start a swarf fire; also if fine machine cuttings are stored in a wet condition or allowed to come into contact with water or other substances capable of giving off oxygen. Given certain unfavorable conditions, dust containing magnesium in the form of very fine powder has exploded. All these matters are not at all of a serious character, provided well-established precautions are adhered to, as would be when handling other fine dusts such as found around flour mills and grain elevators.

There are certain features to be taken into account by the designer wishing to incorporate magnesium alloys in his constructions.

In sand castings the wall thickness should not be less than 0.15 in. Since magnesium alloys are sensitive to conditions of stress concentration, the change from one section to another section of different size must occur gradually. Since the modulus of elasticity amounts to only about 6,000,000 psi., the resonance range of constructional components lies below that for aluminum alloys and heavy metals of similar design. Further, magnesium alloys are apt to distort rather easily under load. It is therefore advisable to support the surrounding metal at the edge of bolt holes and other places subject to stress concentration by thickening the section. In general, it is a good plan to aim for a box-like form of section which possesses a large moment of resistance.

As a result of its elastic behavior, magnesium alloy constructions are less sensitive to sudden blows and they possess great capacity to absorb work. Should serious stress concentration occur by screwing up on assemblage, the low modulus allows the component to accommodate itself, and the resulting stresses are less than they would be for other metals. The power also to absorb noise is useful for gear housings. For bolts often to be unscrewed it is better to put heavy metal thread inserts in the castings.

Magnesium alloys are sensitive to the corrosive attack of many substances. *(Cont. on p. 84)*

Magnesium Castings

(Continued from page 82) Where they come into contact with water they should be given a layer of varnish. Where a varnish is not likely to stand up to vibration in service, or to the impingement of foreign bodies, then magnesium alloys should not be used. A cartridge containing protective substances for insertion into cooling water has been used; alkali-bichromate pickle produces a very effective protection. Intercrystalline corrosion has not been observed. Magnesium alloys are attacked by glycol, glycerine, acid and salt solutions, while alkaline solutions have no action at all below 250° F. It may be necessary to isolate a component in magnesium alloy from its neighbor by a layer of varnish, a sheet of oil paper, or bakelite, though such a procedure is not always necessary and even an oil film is often quite sufficient to protect the metal from corrosion.

In riveting, use rivets of copper-free aluminum alloy; otherwise insulating materials are necessary. This applies specially where riveted jobs are exposed to atmospheric moisture. Where the two parts to be riveted come into contact, they should be varnished or a sheet of insulation inserted as a protection against corrosion.

The magnesium-manganese alloy is especially weldable by the oxy-acetylene process. Special fluxes are necessary during welding, and they must be carefully removed from the joint afterwards. The wire used for welding sheet should be of the same composition as the sheet, and the best welds are obtained only when the two parts to be joined consist of the same alloy. Care should be taken to heat up the casting to 550° F. slowly in a furnace before attempting to weld, and this temperature should be maintained during the operation.

The machining properties are excellent; in fact, better than for any other metal. In view of the high speeds possible, special types of machines are desirable. All cutting tools must be kept sharp. It is better not to use any cooling medium during machining. It is necessary to remove and isolate all accumulations of cuttings. Should a fire arise from the use of a blunt cutting tool, then it can be smothered by cast iron chips. Particular attention should be paid to the adequate removal of magnesium dust produced in grinding operations; this is best done by sucking or drawing the dust into a special collecting chamber. Water-tight iron drums are very satisfactory for storing swarf and dust.

Contributors

ALMOST 30 years' association with openhearth problems for as large and important an organization as American Rolling Mill Co. has made **G. D. Tranter** an authority in this field. He joined Armco in 1911 after graduation from Ohio Mechanics Institute in Cincinnati where he majored in chemistry, and supplemented this work by night school courses in metallurgy. He was successively foreman, assistant superintendent, and superintendent of the openhearth department, and since 1931 has been general superintendent of the Middletown Division of the company. In addition to his practical plant experience, Mr. Tranter has spent some time in Europe, studying operation and metallurgical problems in the steel plants.

Cosmopolite **Lawford H. Fry** was born in Canada and educated in the United States, Canada, England and Germany, where he wound up in 1897 with a year at University of Göttingen and three years at the Technische Hochschule in Hannover. After an apprenticeship in the works of the Southeastern Railway in England, he worked in the erecting shop of the Baldwin Locomotive Works and was subsequently sales engineer, engineer of tests, and technical representative in Europe. In 1913 he was appointed metallurgical engineer for the Standard Steel Works Co., and since 1930 has been railway engineer with the Edgewater Steel Co. in Pittsburgh. He has contributed many articles to technical societies and periodicals on metallurgical subjects and locomotive engineering.

Francis B. Foley, who is an trustee and once served as chairman of the Philadelphia Chapter, was graduated from Girard College, entered the art department of a newspaper, reformed quickly, and then started off in a metallurgical career as a clerk and door-puller in the openhearth department of the Midvale Steel Co. in 1905. Two years later he was promoted to the research staff and remained at Midvale until 1917. Between 1917 and 1926, when he returned to the company as superintendent of research, he engaged in varied activities, mostly with the U. S. Bureau of Mines.

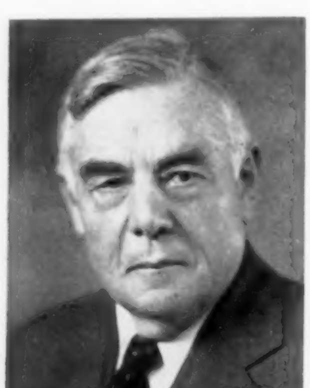
Not a metallurgist by training, but a scientific writer by profession and natural inclination, **Carleton Cleveland** did a great deal of painstaking research in preparing the article on cable materials on page 59. He attended Lewis Institute in Chicago and graduated from one of the professional departments of the University of Illinois. Helping his father in the publishing of medical books led him into the writing field in which he has since been continuously engaged.

Not new to the pages of METAL PROGRESS is the name of **Francis Edwin Bash,** whose article on electrical heating elements supplements one published about two years ago. As research engineer at Leeds & Northrup Co. from 1916 to 1923, Bash helped develop the disappearing filament optical pyrometer and the electrical alloys "constantan" and "manganin". In 1923 he joined the Electrical Alloy Co. in Morristown, N. J., as manager of the technical department, and since 1928 has held the same position with the Driver-Harris Co.

A graduate of Yale's Scheffield Scientific School, **E. K. Smith** started out as chemist for Eastern Malleable Iron Co., Naugatuck, Conn. He journeyed to the Middle West becoming metallurgist and later superintendent for Wisconsin Malleable Iron Co., and then turned southward to join Stockham Pipe Fittings Co., Birmingham, Ala., as metallurgical engineer. He is now service metallurgist for Electro Metallurgical Co. and makes his headquarters in Detroit where he specializes on problems concerning chromium in castings.

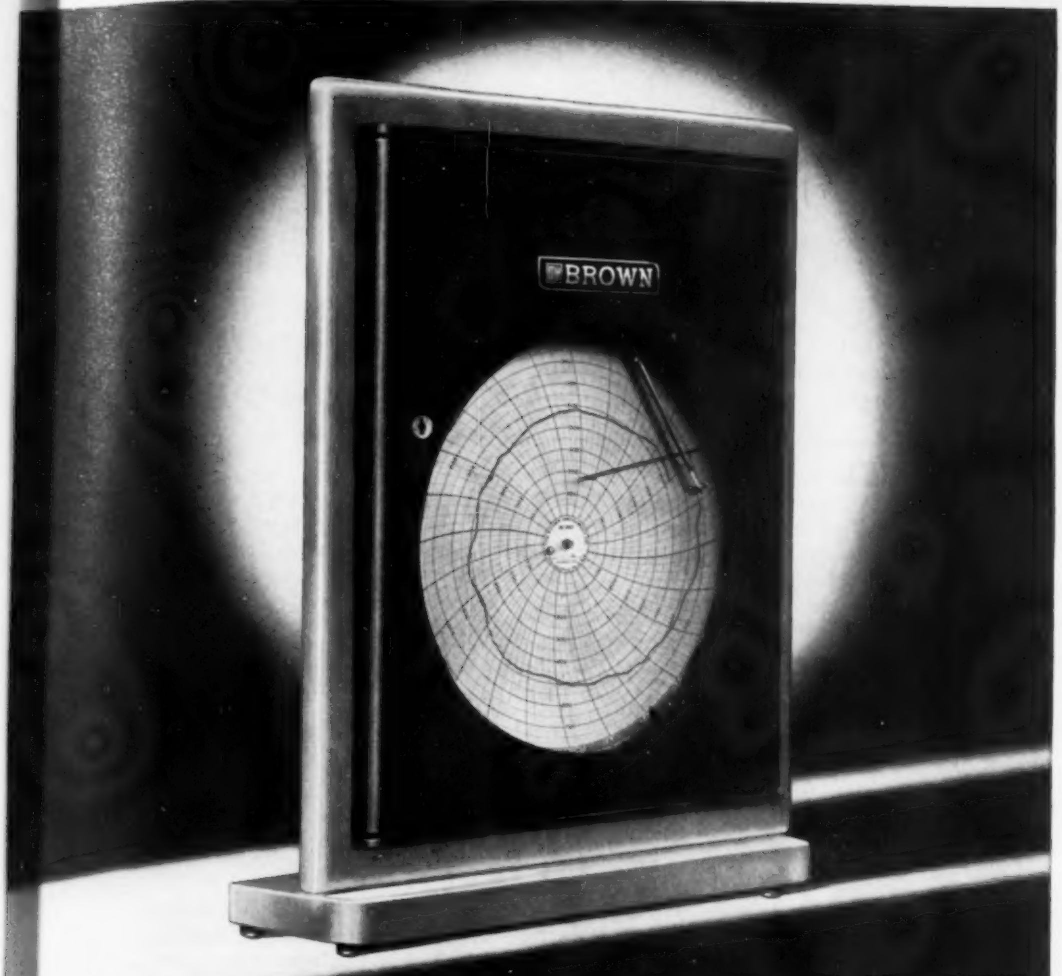
E. K. Smith

Lawford H. Fry



Francis B. Foley

G. D. Tranter



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Carburizing Salt

A technical service bulletin describing a new development—Du Pont Carburizing Salt—for the economical production of deep high-carbon cases on plain carbon and alloy carburizing steels . . . available through Du Pont. Bulletin Dc-29.

Oil Burners

North American Mfg. Co. offers a bulletin describing improved low pressure oil burners, one type especially designed for automatic control and ideally suited for use with proportioning control valves. Bulletin Na-138.

Metallographic Reference

Nearly one thousand technical books and reference papers on Optical Principles in Metallography are listed in the new Metal Analyst just released by Adolph I. Buehler. Bulletin Lc-135.

Design

Designing greater sales appeal into products is explained in a colorful 8-page booklet for anyone who contemplates using, or is using, Stainless Steel, issued by the Carpenter Steel Co. Bulletin Nc-12.

Hydryzing

Hydryzed work is completely described in recent literature released by Lindberg Engineering Co. Points out advantages in particular applications. Bulletin Bc-66.

Seamless Tubes

Prepared by the Timken Steel and Tube Division of Timken Roller Bearing Co. is a "Guide for Users of High Temperature Steels," which presents technical data relating to the various properties of Timken seamless tubes. Bulletin Bb-71.

Colmonoy

The high resistance to wear and corrosion which distinguishes Colmonoy alloys and overlay metals is explained in a 4-page catalog released by Wall-Colmonoy Corp. Bulletin Bc-85.

Lubrication

Intensive research which completed important improvements in the field of heavy-duty gear and bearing lubrication is tabulated in a new 12-page illustrated bulletin just released by D. A. Stuart Oil Co., Ltd. Bulletin Lb-118.

Electromet Review

A very attractive house organ which gives news and views of alloy steels and irons, but is mostly concerned with stainless steels. Electro Metallurgical Co. publishes it. Bulletin Ox-16.

Hardness Testing

A 4-page folder which has as its purpose "to give you an idea of how practical a thing it is to make hardness tests on raw stock or fabricated metal parts in all plants where metal is worked, and to suggest something of the necessity for making such tests, or at least their importance" is available through the Wilson Mechanical Instrument Co., Inc. Bulletin Fb-22.

Foundry Sand

A pamphlet recently issued on TAM Foundry Zircon Sand and TAM Zircon Flour contains detailed information on these products of the Titanium Alloy Mfg. Co. Bulletin Hc-90.

Controlled Combustion

Direct Fired Air Heaters which make possible Controlled Combustion and permit wider range in oven and furnace operation are explained in a 4-page folder by the Despatch Oven Co. Bulletin Lc-123.

Machining Data

A new chart giving the correct grade of Kennametal for machining 21 types of metals, with recommended cutting speeds, has just been made available by McKenna Metals Co. Bulletin Lc-238.

Tocco Process

The marvel of all heat treaters—the Tocco Process of Induction Hardening—is fully described in a colorful folder by the Ohio Crankshaft Co. Bulletin Lc-145.

Ampco Data

An interesting bound volume of Ampco Engineering Data Sheets which give performance records and details about the six grades of Ampco Metal is now available. Bulletin Fc-175.

USE THE COUPON ON PAGE 92 TO OBTAIN THIS HELPFUL LITERATURE

Model "Y"

The Sentry Model "Y" electric furnace, using the Sentry Diamond Block method of heat treatment, provides exceptional quality high speed steel hardening at minimum production cost. The furnace is described in Bulletin Oy-114.

Low Cost Cleaner

A low cost speed-cleaning machine for plants having a rather limited production of small products is introduced in a folder by the American Foundry Equipment Co. Bulletin Ad-112.

No Back-Fire

A burner that cannot back-fire is described in a brand new booklet on the fuel equipment products made by the Eclipse Fuel Engineering Co. Bulletin Ad-226.

High Speed Steel

Required hardness and extraordinary toughness combine to make Firth-Sterling Co. new high speed steel "Mo-Chip" of unusual interest to manufacturers who need a steel that is "practically indestructible." Bulletin Ad-177.

Automatic Arc-Welding

Faster and more uniform welding is claimed for the new G-E automatic arc-welding equipment with thyratron control. A new 16-page booklet describes this product of the General Electric Co. Bulletin Ad-60.

High Speed Recorder

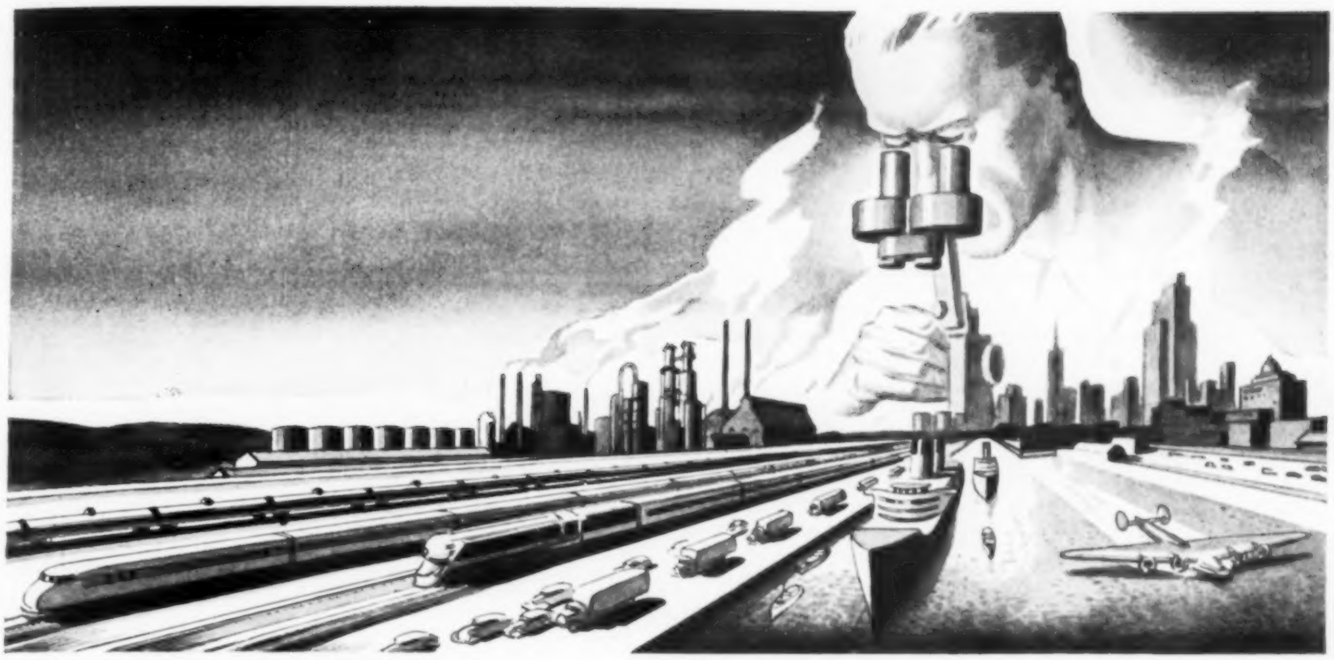
Both roll operator and instrument man will find many advantages in the 1940 model Speedomax high-speed recorder which is introduced in a new, 12-page illustrated bulletin by Leeds & Northrup Co. Bulletin Ad-46.

Lectrodryer

A machine designed specifically for the dehumidification of air and other gases as well as certain liquids—the "Lectrodryer"—is pictured and explained in a booklet by the Pittsburgh Lectrodryer Corp. Bulletin Gc-187.

Dust Collecting

Fourteen outstanding features found in Pangborn dust collectors, along with pictures of typical installations and savings, are found in the new Pangborn Bulletin. Bulletin Ad-68.



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Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc., giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

Aerocase

A modern method for case hardening and heat treating steel in a liquid bath is provided by the use of Aerocase compounds, which have been in commercial use for more than six years. Their principal features are described by American Cyanamid and Chemical Corp. in an interesting booklet. Bulletin Oy-148.

Box-Type Furnaces

The advantages of Hevi Duty box-type electric furnaces are concisely stated in a folder which contains specifications and a fully labeled cross-section of a representative furnace. Bulletin Mx-44.

Thermometers

A new line of thermometers and pressure gauges is announced in a colorful 8-page booklet by the Brown Instrument Co. Bulletin Lc-3.

Heat Treating Furnaces

A brand new 16-page booklet of Holcroft & Company shows and describes their line of controlled atmosphere heat treating furnaces. Bulletin Ec-203.

Pickling Savings

Savings in the pickling department when Monel is used are shown in an illustrated folder just released by the International Nickel Co. Bulletin Ad-45.

Small Appliances

Appliances for use in connection with heat treating are described in a neat booklet by the American Gas Furnace Co. Bulletin Hc-11.

New X-Ray Unit

A new X-ray diffraction unit, smaller and more versatile than previously available outfits of this type, is described in a comprehensive folder just released by the General Electric X-Ray Corp. Bulletin Hc-6.

Low-Alloy Steel

A new folder on Mayari R, Bethlehem's high-strength, corrosion resisting steel, is colorfully illustrated with views of its various uses. Bulletin Kc-76.

Bright Annealing

Various types of electric and fuel-fired furnaces built by the Electric Furnace Co. for bright-annealing wire, tubing, strip and other products are described in an 8-page folder. Bulletin Lb-30.

Cinch Steel Cement

How Cinch steel cement saves high speed steel and Stellite by permitting the using up of short pieces is told in a bulletin by Claud S. Gordon Co. Bulletin Ka-53.

Testing and Controls

An up-to-the-minute booklet on foundry sand testing and control equipment is just off the press. Published by Harry W. Dietert Co. Bulletin Ec-198.

Welding Stainless Steels

A 24-page technical bulletin, giving important information for the engineer, designer or welding operator on the welding of stainless steel, is available through the Arcos Corp. Bulletin Hc-191.

Binocular Microscope

The new Bausch & Lomb wide field binocular microscope permits actual perception of length, breadth, and depth of magnifications from 7 to 150 diameters. The three different models are described in Bulletin Dy-35.

Defi Rust

Analysis and descriptive notes of nine types of heat and corrosion resisting steels made by Rustless Iron and Steel Co. are contained in a handsome folder. Bulletin Ha-169.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Brazing Alloy

Sil-Fos for joining brass, bronze, nickel, nickel silver, extruding brass and bronze, monel metal and other non-ferrous metals and alloys fusing above 1300° F. is a product of Handy & Harman, described in Bulletin Jy-126.

Annual Index

The Annual Index of the Copper Alloy Bulletin published regularly by the Bridgeport Brass Company is now made available through this company. Bulletin Kc-163.

Tube Alloys

Practical data on tube alloys compiled by the Technical Department of the Driver-Harris Co. simplifies calculations by providing derived constants in the shape of tables and formulae. Handy conversion tables included. Bulletin Ib-19.

Chapmanizing

Chapmanizing, the method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given on the method itself and on its metallurgical advantages. Bulletin Ob-80.

General Data Book

Valuable reference and data are contained in a book by Joseph T. Ryerson & Son, Inc., which gives metallurgical definitions, heat, hardness, and numerical equivalent tables as well as many valuable operating facts. Bulletin Nc-106.

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Brittle Constituent

(Cont. from p. 65) 5% ferrite. A 200-hr. anneal at 800° C. increases the hardness only slightly (from Brinell 182 in the quenched condition to 190) but does make the alloy non-magnetic. After a tempering treatment at 950° C. (1750° F.) for 30 min. the alloy returns to its original hardness and is again slightly magnetic.

These phase reactions $\alpha \rightleftarrows \delta + \gamma$ in the Cr-Fe and Cr-Ni-Fe alloys can be studied by magnetic, X-ray and metallographic methods. For metallography an etching solution of 50% HCl, 5% HNO_3 and 45% water is used. Quenched samples then show bright ferrite with distinct boundaries. Such areas appear dark colored in the same etching solution after the sigma constituent has begun to be formed. If the change is far advanced or completed, then the remaining ferrite grains again brighten, although the structure does not appear to be of a single phase; distinct but disseminated and ragged groups of several constituents occur with indistinct grain boundaries.

Embrittlement by the formation of FeCr compound is not confined to the Cr-Fe, Cr-Ni-Fe and Cr-Mn-Fe alloys, but can also occur when ferrite appears in more complex varieties containing ferrite-forming elements. After corresponding annealing treatments a decrease in toughness occurs in these alloys. As an example we might cite an alloy of the following composition: 17.9% Cr, 9.1% Ni, 0.09% C, 0.46% Mn, 0.80% Si, 2.0% Mo, and 1.0% Cb. Molybdenum and columbium induce the formation of about 15% ferrite in this alloy. The table on page 65 gives the properties of this alloy after varying annealing periods at 750° C. (1380° F.). While the yield point and ultimate strength are not markedly influenced, the elongation, reduction of area and notch toughness are considerably reduced, even after as short an annealing as 10 hr.

These results show that the formation of "B constituent" by the change of ferrite into the sigma phase FeCr and austenite is a consequence of the *presence* of ferrite and is not dependent on the composition of the ferrite.

H. Hougardy
Research Laboratories
Deutsche Edelstahlwerke A.G.